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DISPENSER SAFING AND ARMING DEVICE (DSA)

RAYMOND ENGINEERING INC.
217 SMITH STREET
MIDDLETON, CT 06457

NOVEMBER 1976

FINAL REPORT: 14 JANUARY 1975 TO 30 NOVEMBER 1976

AIR FORCE ARMAMENT LABORATORY
AIR FORCE SYSTEMS COMMAND • UNITED STATES AIR FORCE
EGLIN AIR FORCE BASE, FLORIDA

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PREFACE

This report was prepared by Raymond Engineering Inc., 217 Smith Street, Middletown, Connecticut 06457, under Contract F08635-75-C-0125 for the Air Force Armament Laboratory, Armament Development and Test Center, Eglin Air Force Base, Florida. Capt. J. Williams (DLJF) and Mr. R. Mabry (DLJF) were program managers for the Armament Laboratory. This effort was conducted during the period from 14 January 1975 to 30 November 1976.

This technical report has been reviewed and is approved for publication.

FOR THE COMMANDER

WILLIAM F. BROCKMAN, COLONEL USAF
Chief, Munitions Division

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SECTION I

INTRODUCTION

This final engineering report describes and summarizes the efforts conducted by Raymond Engineering Inc. to satisfy the contractual requirements of the Air Force Armament Laboratory for the Dispenser Safing and Arming Device (DSA).

The objective of this program was to design, fabricate and test a prototype DSA based on the MAU-116 S&A for existing MK20 and SUU-54, and future guided and unguided cluster munitions.

SECTION II

DSA DESCRIPTION

The Dispenser Safing and Arming Device (DSA) illustrated in Figure 1 is designed to provide primary weapon safety in all dispenser munitions 10 inches or larger in diameter and equipped with existing, such as in the FMU-110, or future proximity sensors. Basic sequential operating characteristics for the DSA employed in free fall and guide or powered munition applications are illustrated in Figures 2 and 3, respectively.

The DSA is a low-cost hermetically sealed unit, mounting to the forward dispenser bulkhead, immediately aft of the proximity fuze.

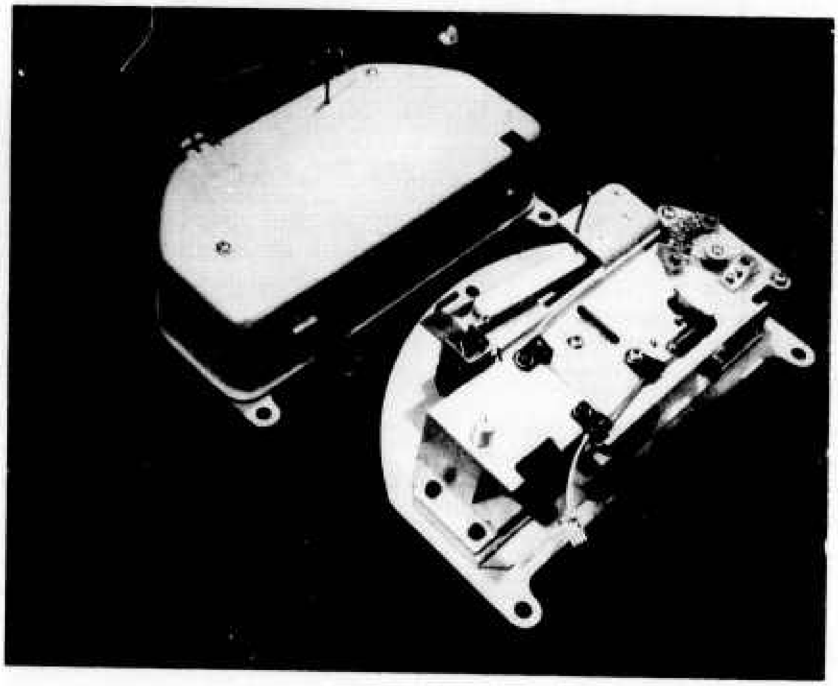
The DSA arms as a result of three sequenced environments: (1) physical release from the aircraft (lanyard), (2) air velocity for a predetermined time interval, and (3) an electrical arming signal from the proximity fuze's safe separation timer.

Upon release from the aircraft, the lanyard removes a tear strip in the DSA housing, allowing erection of an air sensing probe which simultaneously initiates the thermal battery and removes the physical restriction of the rotor and piston shaft elements. The thermal battery is employed to provide energy to the electronic target sensor. In turn the sensor provides a controlled sequence of electrical signals to the DSA's electromagnetic actuator and explosive detonator.

The deployed probe acting in an airstream channels ram air pressure to one face of a piston subassembly. Lower pressure air is conducted through the open tear strip area onto the opposite piston face. Developed environmentally derived differential pressure of a specific magnitude is employed to discriminate a minimum threshold (activation) level and to generate arming energy which moves an explosive interrupter (rotor) from a SAFE out-of-line (0 degrees) to an ARM in-line (90 degrees) explosive train condition and an electrical firing circuit from an open to a closed condition.

The piston must stroke a prescribed distance before rotor release can be effected. Two individual safe separation features sequentially control the rotor's travel before it can proceed to the ARM position.

Interaction with a mechanical timer governs the rate at which the rotor travels during its initial motion (30 degrees in 1.5 to 2.0 seconds) before 15 degrees of free travel brings the rotor to an intermediate stop position. Further rotor travel is restricted by the physical interference of an electromagnetic actuator arm.



Top - With Case Installed
Bottom - Case Removed

Figure 1. Dispenser Safing and Arming Devices

	TIME	PRELAUNCH	0 LAUNCH	1 SECONDS	2	3	TX
	MUNITION STATUS	CAPTIVE FLIGHT	FREE FALL				
BASIC S&A FUNCTIONS	LANYARD	CAPTIVE	RELEASED				
BASIC S&A FUNCTIONS	SEAL	HERMETIC	PENETRATED				
BASIC S&A FUNCTIONS	PROBE	LOCKED AND STORED	RELEASED AND DEPLOYED				
BASIC S&A FUNCTIONS	BATTERY	INACTIVE	ACTIVATED				
BASIC S&A FUNCTIONS	PISTON	LOCKED	A FULL DISPLACEMENT BY AIR PRESSURE ASSOCIATED WITH MUNITION VELOCITY				
BASIC S&A FUNCTIONS	FLECTION SPRING	NO STORED ENERGY	B STORED ENERGY TRANSFERRED TO DRIVE ROTOR		STORED ENERGY	ENERGY RELEASED TO DRIVE ROTOR TO ARM POSITION	
BASIC S&A FUNCTIONS	ROTOR	LOCKED IN SAFE POSITION	UNLOCKED ROTATION UNDER INFLUENCE OF ESCAPEMENT TO INTERMEDIATE POSITION		HELD IN POSITION BY SOLENOID RESTRICTION	SNAP TO FULL ARM POSITION BY SOLENOID RELEASE AND LOCKED IN ARM	
BASIC S&A FUNCTIONS	EXPLOSIVE TRAIN STATUS	SAFE OR OUT OF LINE	MOVING TOWARD ARM		LOCKED AT INTER LOCATION	ARM OR IN-LINE	INITIATED
BASIC S&A FUNCTIONS	ESCAPEMENT	ENGAGING LOCKED ROTOR	CONTROLLING ROTOR ROTATION FOR 1.5-2.0 SEC.		DISENGAGED FROM ROTOR		
BASIC S&A FUNCTIONS	ELECTRICAL CIRCUIT TO DETONATORS	ATTACHED TO ROTOR (OPEN)	ROTATING WITH ROTOR (OPEN)		(OPEN)	(CLOSED)	(CLOSED) CONDUCTS POWER TO DETONATOR
BASIC S&A FUNCTIONS	SOLENOID	SPRING LOADED TO ENGAGE ROTOR				C SPRING LOADED TO ENGAGE AND LOCK ROTOR	
MUNITIONS	ELECTRICAL SAFE SEPARATION TIME SIGNAL	INACTIVE	ACTIVE (SELECTABLE TIME PRESET ON GROUND. MINIMUM TIME = 3 SECONDS)			D EXPIRED	
MUNITIONS	ELECTRONIC TARGET SENSOR	INACTIVE		ACTIVE			SENSES TARGET
MUNITIONS							
SUPPLEMENT							
SUPPLEMENT							

A	RELEASED	B	ENERGY STORED BY PISTON DISPLACEMENT	C	ROTOR RESTRICTION REMOVED INSTANTLY
D	PROVIDES SIGNAL TO SOLENOID AT SAFE SEPARATION TIME EXPIRATION				

Figure 2. Free Fall Sequential Operations

	TIME	PRELAUNCH	0 S&A ACTIVATION	1	2 SECONDS	3	TX
	MUNITION STATUS	CAPTIVE FLIGHT	INDEPENDENT FLIGHT				
BASIC S&A FUNCTIONS	LANYARD	CAPTIVE	RELEASED				
BASIC S&A FUNCTIONS	SEAL	HERMETIC / OPTION PENET.	PENETRATED				
BASIC S&A FUNCTIONS	PROBE	LOCKED AND STORED	RELEASED AND DEPLOYED				
BASIC S&A FUNCTIONS	BATTERY	INACTIVE	ACTIVATED				
BASIC S&A FUNCTIONS	PISTON	LOCKED	A FULL DISPLACEMENT BY AIR PRESSURE ASSOCIATED WITH MUNITION VELOCITY				
BASIC S&A FUNCTIONS	FLECTION SPRING	NO STORED ENERGY	B STORED ENERGY TRANSFERRED TO DRIVE ROTOR		STORED ENERGY	ENERGY RELEASED TO DRIVE ROTOR TO ARM POSITION	
BASIC S&A FUNCTIONS	ROTOR	LOCKED IN SAFE POSITION	UNLOCKED ROTATION UNDER INFLUENCE OF ESCAPEMENT TO INTERMEDIATE POSITION		HELD IN POSITION BY SOLENOID RESTRICTION	SNAP TO FULL ARM POSITION BY SOLENOID RELEASE AND LOCKED IN ARM	
BASIC S&A FUNCTIONS	EXPLOSIVE TRAIN STATUS	SAFE OR OUT OF LINE	MOVING TOWARD ARM		LOCKED AT INTER LOCATION	ARM OR IN-LINE	INITIATED
BASIC S&A FUNCTIONS	ESCAPEMENT	ENGAGING LOCKED ROTOR	CONTROLLING ROTOR ROTATION FOR 1.5-2.0 SEC.		DISENGAGED FROM ROTOR		
BASIC S&A FUNCTIONS	ELECTRICAL CIRCUIT TO DETONATORS	ATTACHED TO ROTOR (OPEN)	ROTATING WITH ROTOR (OPEN)		(OPEN)	(CLOSED)	(CLOSED) CONDUCTS POWER TO DETONATOR
BASIC S&A FUNCTIONS	SOLENOID	SPRING LOADED TO ENGAGE ROTOR				C SPRING LOADED TO ENGAGE AND LOCK ROTOR	
MUNITIONS	ELECTRICAL SAFE SEPARATION TIME SIGNAL	INACTIVE	ACTIVE (SELECTABLE TIME PRESET ON GROUND, MINIMUM TIME = 3 SECONDS.)			D EXPIRED	
MUNITIONS	ELECTRONIC TARGET SENSOR	INACTIVE		ACTIVE			SENSES TARGET
MUNITIONS	S&A ACTIVATION TIME SIGNAL	INACTIVE ACTIVE	E EXPIRED				
SUPPLEMENT	S&A ELECTRICAL ACTIVATION DEVICE	INACTIVE	F EXPIRED				
SUPPLEMENT							

A	RELEASED	B	ENERGY STORED BY PISTON DISPLACEMENT	C	ROTOR RESTRICTION
D	PROVIDES SIGNAL TO SOLENOID AT SAFE SEPARATION TIME EXPIRATION	E	PROVIDES SIGNAL TO S&A ELECTRICAL ACTIVATION DEVICE	F	INITIATES S&A

Figure 3. Powered Flight Sequential Operation

Rotor release from the intermediate stop allowing snap movement to the ARM position takes place when an electrical signal is supplied from the proximity sensor's safe separation timer to the DSA's electromagnetic actuator. The rotor is locked in the ARM position by the deenergized electromagnetic actuator.

The DSA is equipped with a fixed MK71 electrical detonator and a MK9 lead, installed in the rotor. When an electrical firing signal from the proximity fuze is conducted through the closed circuit to initiate the electrical detonator, the aligned MK9 output ruptures the DSA case to initiate any of a variety of attached MDF lines for center or tangential, single or multiple initiation of dispenser opening.

Figures 4 through 8 show the internal mechanism configurations in major operational positions.

Differential pressure corresponding to 150 knots or more for 1.5 to 2.0 seconds will effect arming; at delivery velocities of 120 knots or less, the DSA will not arm. (Note: airspeeds given here are specified design goals.)

If differential pressure associated with air velocity decreases below the specified threshold level prior to the activation of the electromagnetic actuator, the DSA will reset to the SAFE position. In addition, battery life of one minute determines the usable life of the device after actuation under both GO and NO-GO conditions, providing a high degree of system safety.

Models built and tested during this program made use of concepts and components developed for the MAU-116 S&A designed for the FMU-79 Rockeye dispenser which met 150 knots NO-GO, 180 knots ALL-GO prescribed for that configuration. Since the DSA design contains additional Return-to-Safe features that were not incorporated in the MAU-116 design, and which do reduce the net arming forces, the operational ALL-GO and NO-GO characteristics of the DSA model are in excess of those of the MAU-116. A comparison of the respective features of the DSA and the MAU-116 are shown in Table 1.

The DSA, Raymond Model 2356, shown in Figure 1, is 8.9x5.7x2.4 inches and weighs 2.7 pounds.

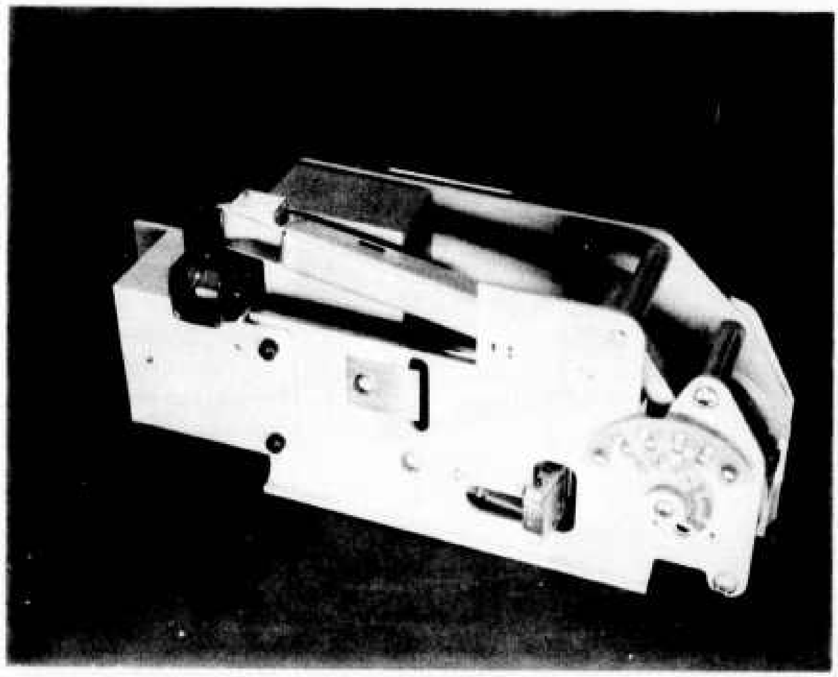


Figure 4. DSA Forward Face View in Preactuated Position

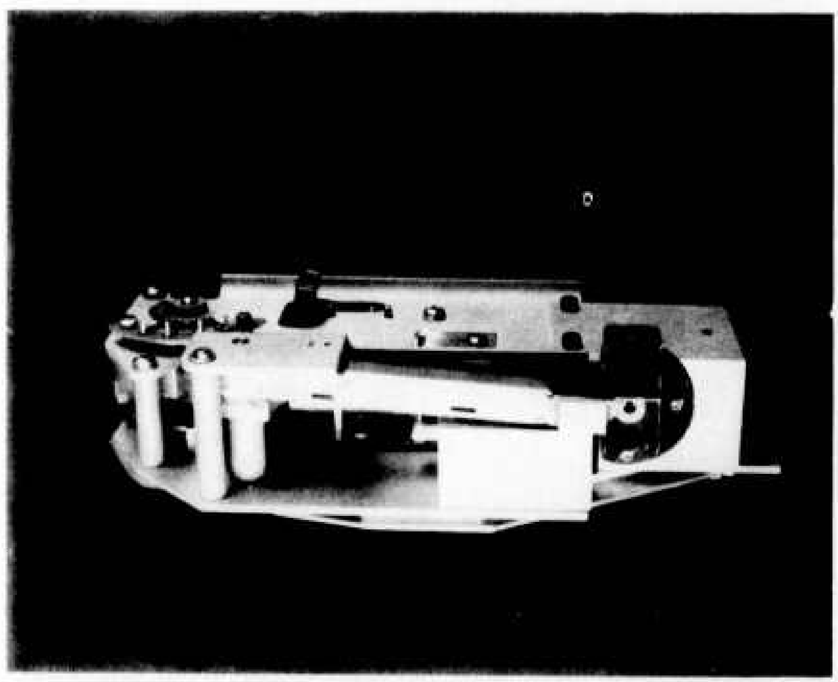


Figure 5. DSA Top View in Preactuated Position

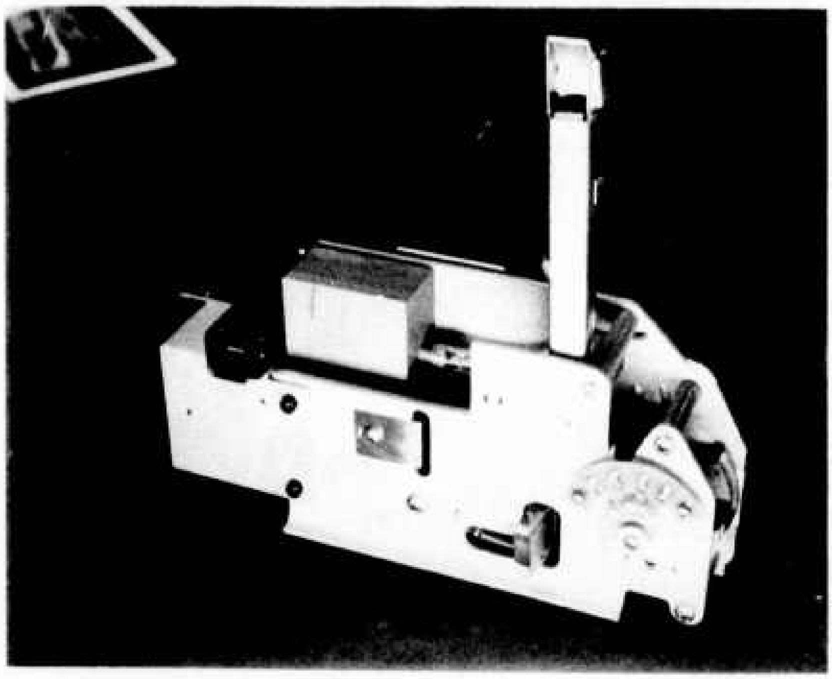


Figure 6. DSA Forward View with Probe Extended

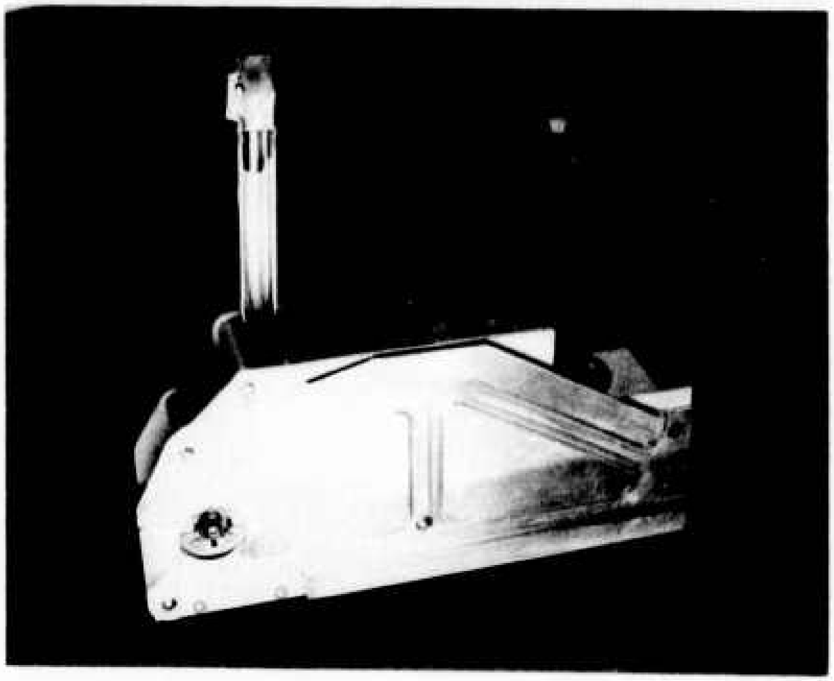


Figure 7. DSA Rear View with Support Plate in Actuated Position

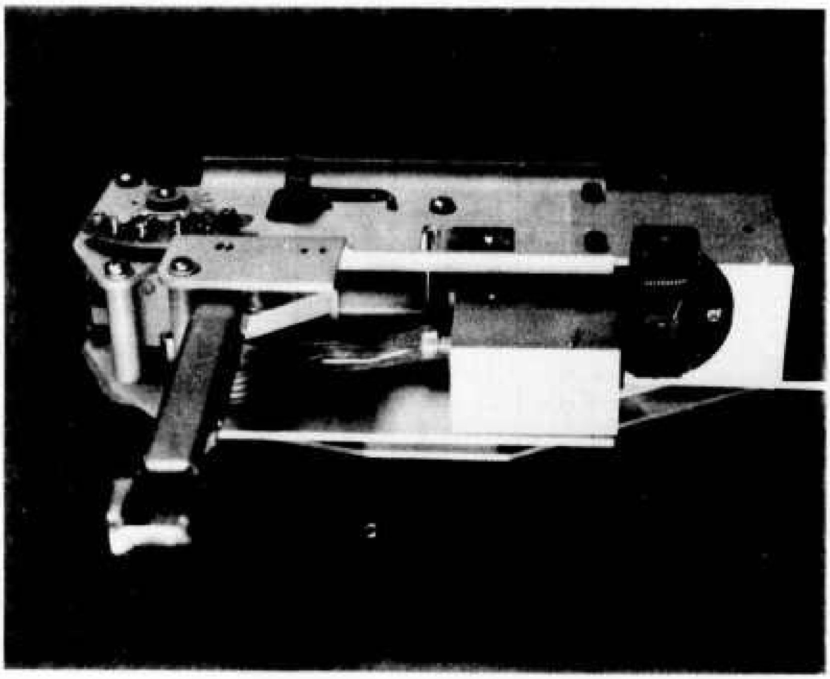


Figure 8. DSA Top View in Actuated Position

TABLE 1. COMPARISON OF MAU-116 AND DSA ROTOR DRIVE CHARACTERISTICS

Element Description	MAU-116	DSA
A. Piston	Rectangular diaphragm with hemispherical ends. Force obtained from imposed air pressure to react against flection spring.	Same dimensions and characteristics as MAU-116.
B. Minimum Actuation (ALL-GO) Air Velocity	220 knots	150 knots
C. Velocity Discrimination Feature	Flection spring buckling level.	Same mechanism at lower value.
D. Arming Force	Flection spring energy stored by piston stroke and force.	Same mechanism with lower energy level.
E. Escapement	MK330	MK330
F. Escapement Drive	Separate mechanism powered by individual spring energy which removed rotor lock after expiration of fixed time period.	Driven by arming force through gear segment fixed to rotor.
G. Intermediate Stop	None	Electromagnet mechanism restricts rotor travel beyond 45 degrees from SAFE position.
H. Runaway Escapement Feature	Timer (escapement) mechanism contains control cam profile that will lock rotor if cam rate of rotation is excessive.	Electromagnet mechanism serves as a secondary safe separation control. Activation signal received from sensor's electronic timer.
I. Rotor Preactivation Lock	Gate and timer cam restriction with piston shaft position.	Probe cam interface and piston shaft position.
J. Rotor Safe Lock	Timer cam/plunger mechanism blocks rotor motion until safe separation time expires.	Erection of probe and full displacement of piston shaft immediately releases rotor to respond to flection spring force through the rate controlling escapement.

TABLE 1. COMPARISON OF MAU-116 AND DSA ROTOR DRIVE CHARACTERISTICS (Concluded)

Element Description	MAU-116	DSA
K. Rotor SAFE to ARM Travel	Snaps full 90 degrees from SAFE to ARM position under influence of flection spring energy.	Under influence of flection spring energy, the rotor moves through 40 degrees of escapement controlled rotation, then is released to snap an additional 5 degrees to be refrained from further travel by the electromagnet mechanism. After expiration of a preset time period, the rotor is again released to snap the remaining 45 degrees to the ARM position.
L. Rotor ARM Lock	Plunger mechanism mechanically locks rotor into ARM position.	Rotor is locked in ARM by deactivation of electromagnet mechanism.
M. Air Pressure Loss Prior to Mechanical Time Expiration	Results in direct return of piston back to initial position via stored energy of flection spring and removes any forces tending to arm the rotor.	Rotor remains engaged with escapement gear train. Energy stored flection spring will tend to dissipate in the direction of least resistance which will return piston toward the initial position in proportion to the arc traveled by the rotor from the SAFE position. All forces tending to arm the rotor will be removed.
N. Air Pressure Loss after Expiration of Mechanical Time	Unless rotor release and air pressure loss occur simultaneously, rotor will snap 90 degrees to ARM position and lock in place.	If flection spring energy is dissipated before activation of the electromagnet mechanism, full return of piston and rotor is not insured unless a separate restoration force is introduced.
O. Rotor Return to Safe Feature	None	Incorporation of an independent counter to ARM torque spring tending to SAFE the rotor.

Though a new dispenser configuration which could have a forward bulkhead diameter of 14.000 to 16.000 inches was the principal design motivator, the S&A configuration did consider interfacing with the bulkheads of existing munition hardware as illustrated in Figure 9. In order to accommodate the large positional variations in explosive initiation points, the S&A's maximum outer profile is contained within an area scribed by a 5.000-inch radius having a center point that is free of any S&A structure that would prevent the installation of a flexible explosive line between the S&A's explosive output and the dispenser's explosive input(s).

Detailed evaluations of all potential bulkhead configurations were not conducted. It is recognized that the rear flat plate surface of the S&A containing the present three-hole mounting pattern may not be compatible with all bulkhead surfaces from which boltheads, valves, ribs, etc., may project and that the bulkhead's wall thickness in certain areas may restrict or prevent use of fasteners.

The forward flat cover surface of the S&A is designed to provide clearance with an electronic target detection device which will be mounted to an independent munition support structure.

Basic input and output functions such as probe deployment, electrical connection, explosive interface and visual status verification are contained along the S&A's peripheral surface within the overall depth of 2.130 inches.

Tangentially mounting the S&A to the munition's superstructure permits:

(a) Effective deployment of the probe into the airstream
(b) Visual verification of the rotor's position or status (SAFE or ARM).

The modified circular segment S&A profile allows the electrical and explosive interfaces along the chordal surface to extend to the munition's electronic sensing device and/or to any electrically powered auxiliary systems or to the explosive initiation points. Flexible mild detonating fuze line or lines will be employed to transfer the S&A's explosive output to the specific munition's explosive interface.

2.1 SUPPORT AND CASE STRUCTURE

Two support structures are employed to establish and sustain the relationship of the main S&A elements. Two shallow channel plates held at a fixed distance by support posts maintain the probe, piston, rotor, escapement and electromagnet subassemblies in proper association with each other (see Figures 4, 5 and 6).

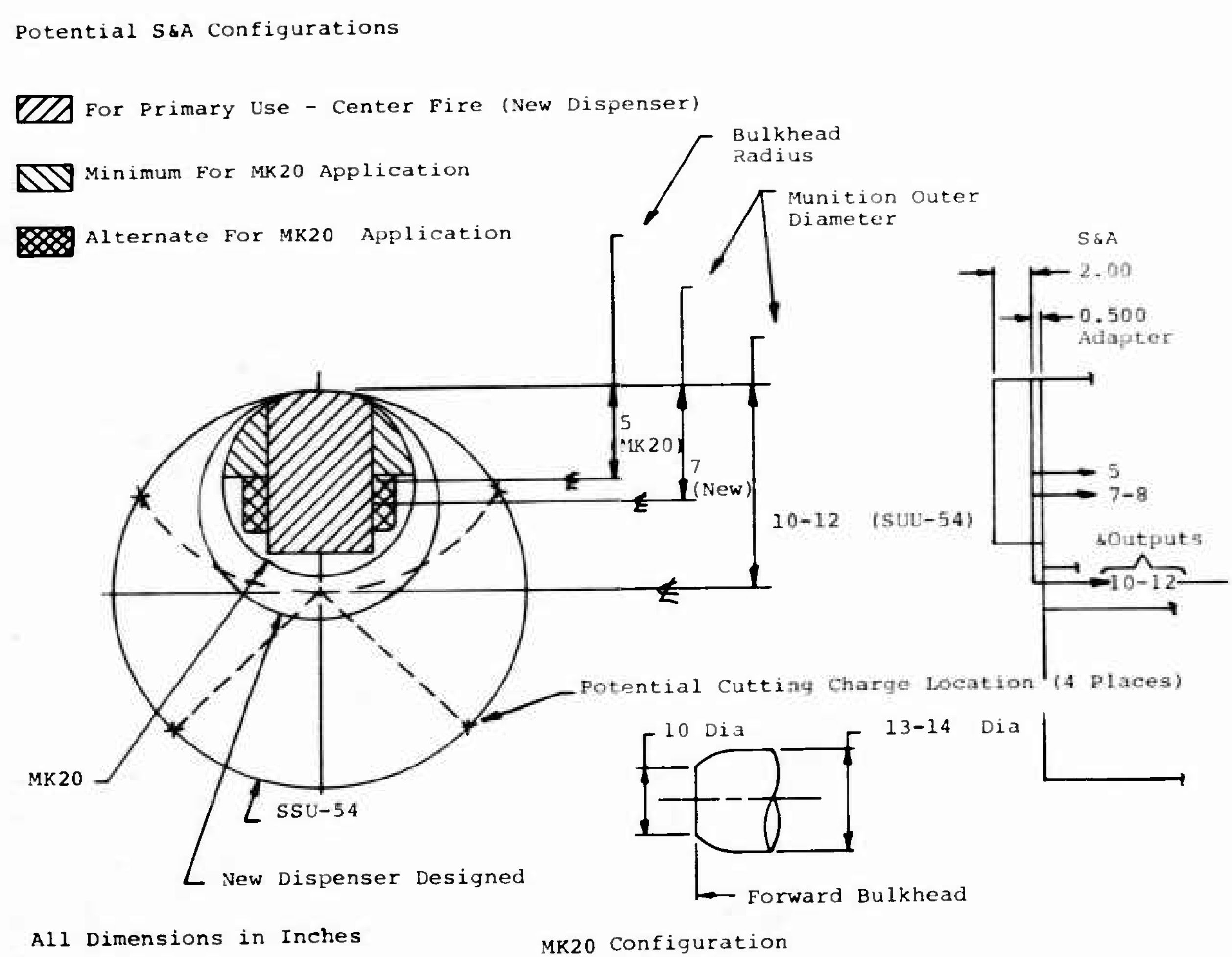


Figure 9. Available Envelopes For Dispenser S&A

A ribbed support plate is used to provide a locating substructure for the channel plate assembly, battery and case. The case interfaces with the base of the support plate to provide facilities for input, output and sealing functions (see Figure 7).

2.1.1 Channel Plate Structure

Two parallel formed plates, maintained at a fixed distance apart by a series of posts, establish the functional relationships between the probe, piston, rotor, escapement and electromagnet subassemblies. This modular construction permits assembly and test of the major operational components before the channel plate assembly is fastened to the support plate structure.

2.1.2 Support Plate Structure

Providing a rigid foundation to which the battery, channel plate, and case are affixed, the support plate structure consists of two components.

In the initial development models, a formed support plate was welded to the inside surface of the bottom cover. Three right angle brackets welded to the cover formed the bulkhead mounting pattern.

Final models consisted of a contoured flat base plate with three integral mounting holes welded to the formed support plate.

Self-clinching threaded fasteners were inserted in the support plate to retain the battery and channel plate assemblies in a relationship that controls the pre-initiated positions of the battery striker and the probe. The case is located against two support plate surfaces and the flat base plate surface to establish probe deployment, explosive output and sealing features. Tooled high production design could result in the unification of the support and base plates and the elimination of the inserted threaded fasteners as a minimum and have the added potential of incorporating the bottom channel plate features.

2.2 CASE

Primarily a covering element that seals and protects the internal components, the case provides features for the:

(a) Electrical connector
(b) Mounting facilities for the MDF explosive output
(c) Probe deployment
(d) Rotor status (SAFE or ARM) window
(e) Lanyard activation system
(f) Sealing interface
(g) Safety wire.

2.2.1 Configuration

The case design applied to the initial development test models is shown in the photographs in Section IV. Two standard stock aluminum formed covers were mated to form a structure that sealed the internal mechanism from environmental exposure. The rear cover, which is welded to the base plate structure, contained the electrical connector and three leg brackets that secured the S&A to the bulkhead. The top cover contained the probe deployment, lanyard activation and rotor status mechanisms.

Configuration of the final case design illustrated in Figure 1 consisted of a single deeper drawn element fastened directly to a base plate structure. Mounting the S&A subassemblies to a single rigid base plate allows:

(a) Installation of the explosive detonator and soldering of its leads to the electrical circuit.

(b) Inspection and testing of fuze functions before the case is applied and a seal is generated between the two members.

2.2.2 Materials

Material selection was based on the mechanical properties, protective processes, sealing (welding) and cost characteristics.

Employment of both aluminum and stainless steel external case members was evaluated. Though there was a preference for the beneficial physical properties of stainless, the development model cases were constructed from aluminum because of advantages in limited fabrication and "rip off" strip configuration.

2.2.3 Sealing

In production, the final seal of 10^{-6} would be generated when the case is welded to the base plate. The case elements under this contract were not welded to the base plates in order to allow disassembly for continual test and evaluation. During development tests, the case was held in place by screws and seal surfaces were taped to prevent contamination.

2.2.4 Probe Deployment

Withdrawal of a portion of the case surface removes the restriction of a spring-loaded probe and allows it to deploy.

Fracturable materials, "rip off" strips and puncturable membranes were among the alternative seal removal methods evaluated. Removal of the "rip off" strip seal would be by direct pull force. For fracturable materials or puncturable membranes, the direct pull force would be transferred to a secondary spring-loaded device which could act directly or could activate a percussion initiated explosive device.

Puncturable membranes were most compatible with linear displacement probes such as those employed in MAU-116 and Harpoon S&A designs. Incorporation of fracturable materials was considered to be an expensive process.

The "rip off" strip employing direct pull forces to accomplish its removal was selected as the most practical and economical approach for the probe configuration.

2.2.5 Compartmentalization

Whenever a sealed case section is intentionally or accidentally open to the environment, the internal mechanisms are subject to potential contamination. Primarily important when the S&A is being employed on munitions having long extended independent flight time to target, the S&A's electrical circuitry should be isolated and protected.

Various alternatives for sealing the deployed probe from the remaining S&A mechanism were evaluated but each presented some unique constructional or operational problem.

As a minimum, the proposed design can isolate the rotor's electrical firing circuit and the electrical detonator by providing a sealed cover that interfaces with the upper channel plate.

2.2.6 Safety Wire

To facilitate continual evaluation of the internal mechanism, the present design employs a safety wire arrangement that violates the hermetic seal concept by passing through the base plate and case to intercept the probe structure and prevent its deployment.

For sealed units, a rigid member secured between the threshold bracket and the lanyard cable would be intercepted by a safety pin which would transfer the lanyard tension through a bracket to the case instead of imposing it upon the threshold shear pin (Figure 10).

2.3 ACTUATION MODES

The proposed S&A is adaptable for use with several types of dispenser weapon system missions:

(a) Unguided free fall
(b) Guided glide
(c) Guided power.

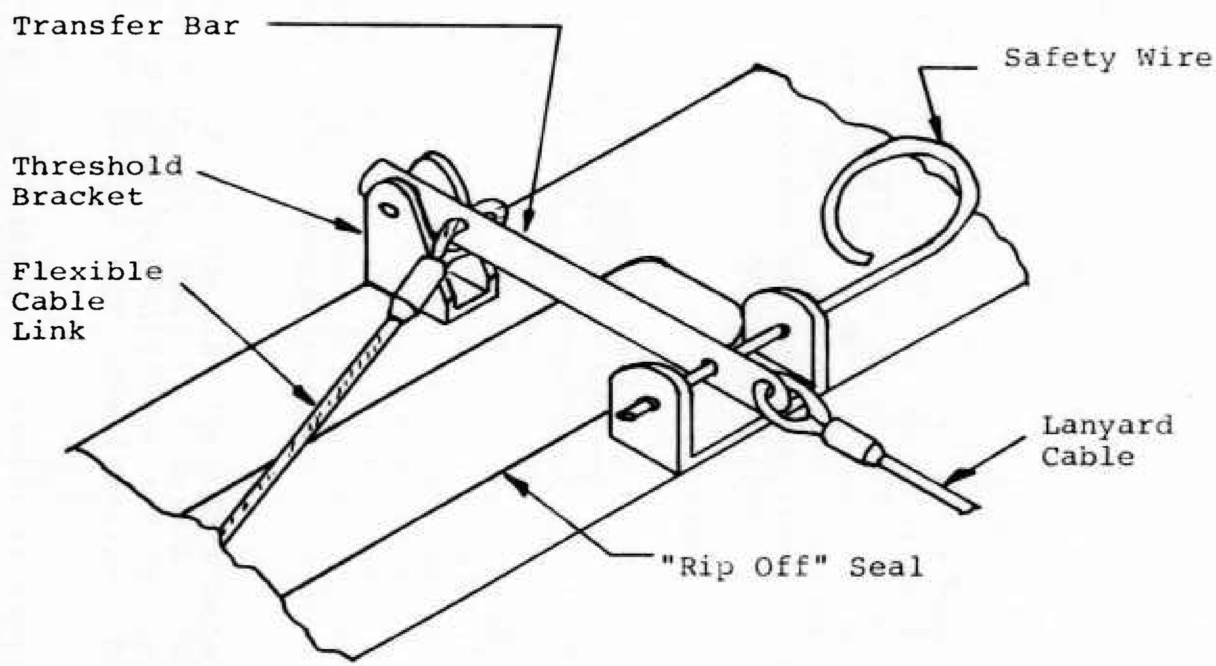


Figure 10. Safety Wire Concept

In the unguided free fall mode, the S&A would be activated by a lanyard system after launch from the aircraft. For guided glide or power flight, the lanyard system will remove the seal strip but the activation of the S&A will be delayed for a period of time by a secondary electrically activated release system which will allow the munition to fly within range of the target before initiating the short life thermal battery.

2.3.1 Secondary Actuation Mode

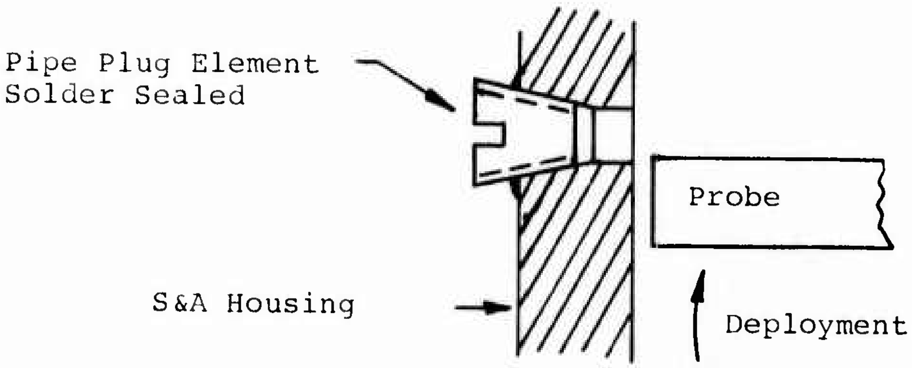
Two lanyards may be employed for the total munition. The second lanyard will be used to complete an electronic sensor by-pass circuit that will allow munition initiation at whatever time the rotor snaps into the arm position. Though this switch feature was not incorporated into the present S&A design, its eventual location can be within the present S&A structure or as an individual switch component external to the S&A. Similar to the MAU-116 device in function, the withdrawal of only the primary arming wire will command the munition to initiate upon receipt of signals from the electronic sensor. Withdrawal of both arming wires will create an electronic sensor by-pass circuit and munition initiation will occur whenever the mechanical arming process has moved the rotor to the ARM position.

2.3.2 Electrical Activation

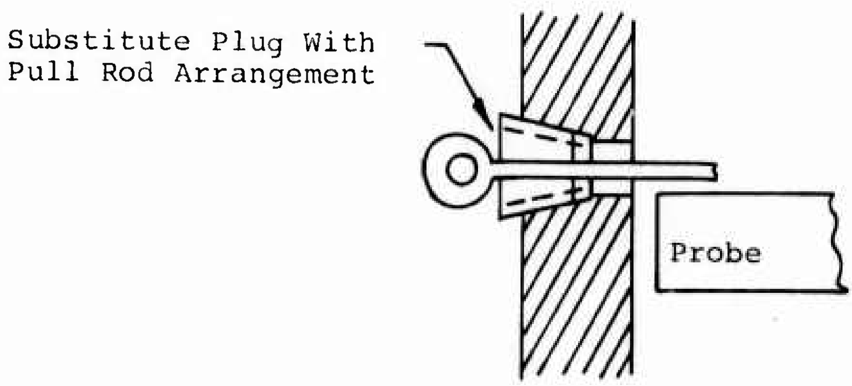
Delay in S&A activation is required to conserve limited thermal battery power whenever a long term independent munition flight profile is introduced. A secondary electrically activated release mechanism will be field installed and mounted to the standard S&A configuration. After the lanyard system has removed the primary restriction by withdrawing the seal case section, the secondary release mechanism will intercept the probe to prevent its deployment and the battery's initiation. This secondary actuation system which shall not be capable of overriding the mechanical lanyard activation system, will remove its restriction of the probe upon receipt of an electrical signal from the munition system.

Figure 11 illustrates a concept that employs a threaded plug that remains in place when a free fall flight is scheduled. A modified threaded plug with a translating rod is substituted when the externally mounted electrical secondary activation device is installed.

Figure 12 illustrates an internal secondary electrical activation concept that would utilize the electrical arm electromagnet to remove the restriction of the rotor and release the spring loaded probe whenever an externally generated electrical signal is applied. Deenergizing the electromagnet will allow the spring loaded arm to displace back to a position that would intercept the rotating rotor's profile at the intermediate or electrical arm stop position. A second electrical pulse will remove the intermediate stop restriction allowing the rotor to snap into the ARM position.



Free Fall Mode



Guided Weapon Mode

Figure 11. Plug Configurations

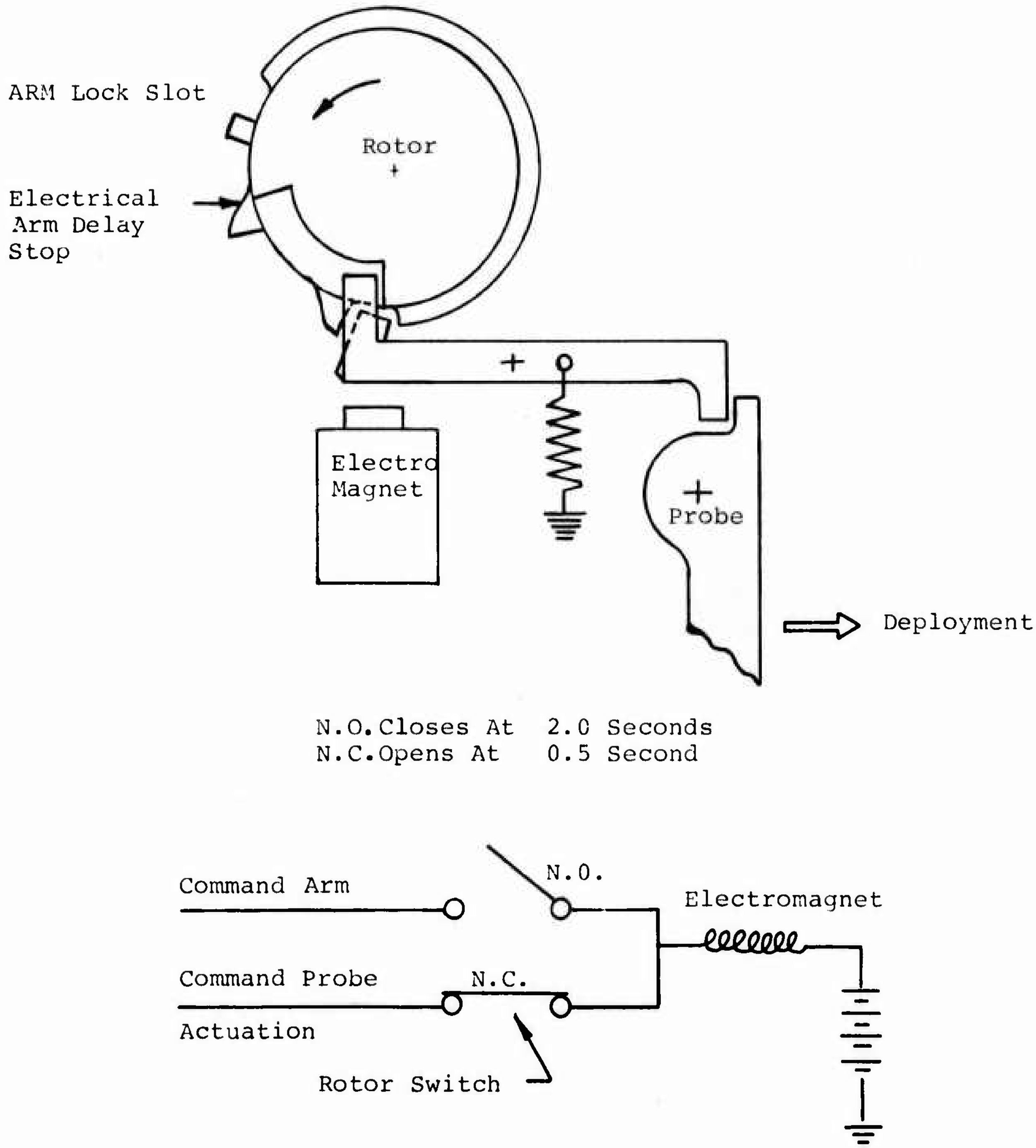


Figure 12. Electrical Actuation Option

Subsequent electromagnet deenergization would lock the rotor in the ARM position.

This system would not be field installable and could only be used with munition systems that have an independent external electrical signal source available at S&A activation.

2.3.3 Lanyard Activation

The DSA lanyard system consists of:

(a) Safety wire
(b) Lanyard cable
(c) Threshold mechanism
(d) Flexible link
(e) "Rip off" seal bracket.

After the DSA is secured to the munition bulkhead, the end of the lanyard cable is passed through the munition's stop bracket and assembled into the MAU-162 lanyard adjustment mechanism.

To minimize captive flight airstream effects, the lanyard's path from the munition guide channel to the threshold mechanism will be parallel to the munition's longitudinal axis. Along this initial line of action (zero degrees), the lanyard will originate at the MAU-162, pass through the munition's stop bracket and terminate at the threshold bracket. The lanyard's path is predetermined to cross over the removable seal area with sufficient tension and in such a way that failure of the seal section prior to intentional activation will intercept the probe as it begins to deploy and will prevent its exposure to the direct airstream.

The closed loop end of the lanyard cable is secured around a calibrated shear pin that is rigidly supported within the threshold bracket welded to the case structure. Applied along this initial line of action (zero degrees), a 50-pound lanyard pull force will react against the threshold or weak-link pin, causing it to shear.

Coupled to the lanyard cable's closed loop end is one closed loop end of the flexible link cable. A tension-free section of lanyard, the flexible link provides a connection between the lanyard cable end retained at the threshold mechanism and the bracket mounted directly to the removable seal.

To protect the flexible link from effects of a captive flight airstream, a plate is extended from the face of the forward case to shield the area between the two brackets.

Secured to the "rip off" seal is a bracket that provides a moment arm to effect seal section removal whenever a pull force of 55 pounds maximum is introduced to the flexible link. The seal bracket is designed to:

(a) Have minimum projection above the munition profile
(b) Prevent excessive exposure of the flexible link to airstream cross flow during captive flight
(c) Provide optimum angle of pull for effective seal removal at the selected pull force magnitude.

To effect a hermetic seal prior to intentional munition release and to remove that seal with its obstruction to probe deployment after munition release, a "rip off" section having a 4.450 by 0.75 inch rectangular profile with a 0.010 inch material thickness within a 0.032-inch wide groove was incorporated.

At launch, the lanyard cable tension resulting from munition separation from the aircraft will first react against the threshold mechanism to provide initial release characteristics before transfer of the tension to the flexible link to remove the case's seal section. Transfer of tension to the flexible link changes the lanyard system's line of action at the munition's stop bracket from a maximum of 30 degrees as seal removal is completed (see Figures 13 and 14).

When lanyard tension exceeds the 86 pounds minimum and prior to reaching the 125 pounds maximum actuation limit of the MAU-162 lanyard adjuster, the MAU-162 will release the munition from the aircraft. To provide this tension level a lanyard stop bracket, which will be capable of withstanding the shock load developed as the mechanical restriction in the lanyard cable interacts with it, will be provided on the munition's superstructure.

To provide a more efficient angular pull relationship between the seal strip bracket and the stop mechanism, a rigid or flexible extension pivoting from a place along the munition skin, as shown in Option II of Figure 14, could provide an improved force vector.

2.4 PROBE

Delivery of the ram (maximum) air pressure associated with the munition's flight profile to the DSA's sensor is accomplished by projecting a probe into the free airstream. Withdrawal of the case's rectangular sealed section removes the restriction to the probe's deployment and provides an aspiration (minimum) air pressure source.

Two kinds of probe designs were investigated:

(1) Linear deployment
(2) Radial deployment.

The linear type was similar to that employed in Harpoon (gas generator activated) and in the MAU-116 (spring energy).

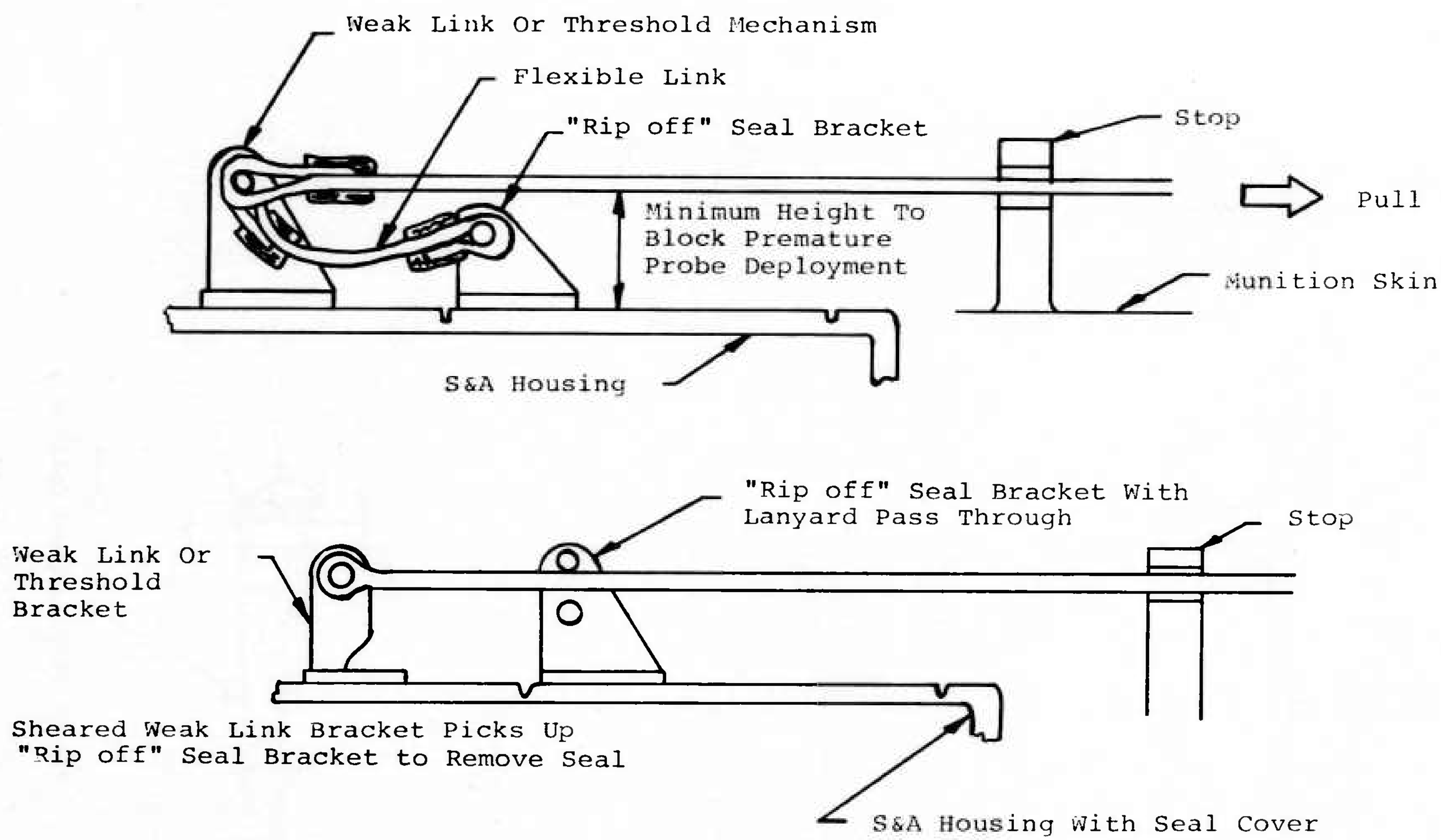


Figure 13. Threshold Options

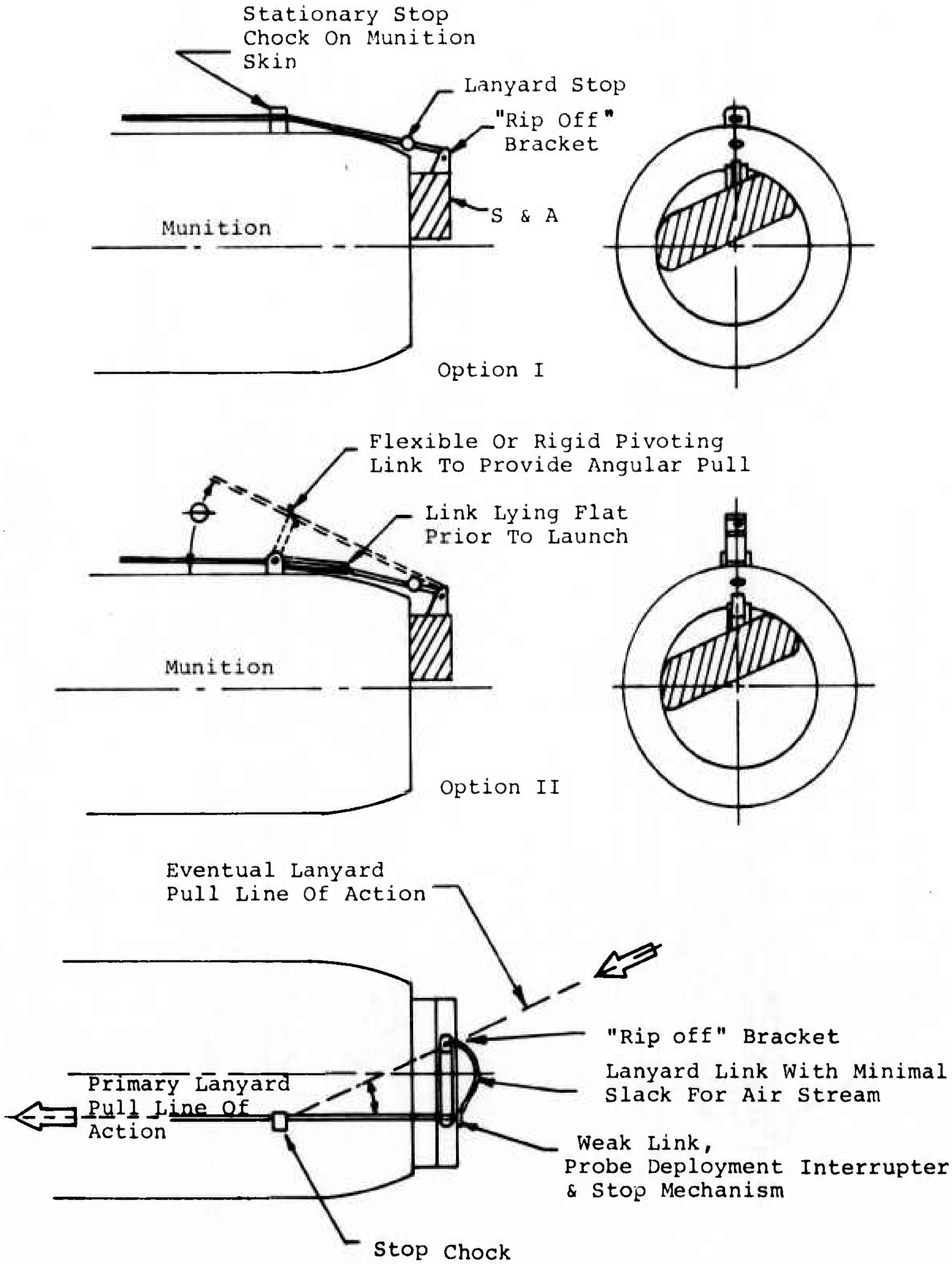


Figure 14. Lanyard Options

Linear displacement probes have the advantage of having only to rupture a relatively small circular disc seal. However, to provide adequate deployment height, a substantial mechanical spring or gas generator mechanism must be employed to shear the seal and deploy the probe.

Radial deployment similar to that used in Walleye units requires the exposure of a larger area in order to effectively deploy a pivoting probe.

Minimum probe extension beyond the munition skin is dependent upon the air flow characteristics generated under all possible munition free flight attitudes. Based on information from similar applications, an estimated projected height of 2.625 inches minimum was established.

A radial pivoting probe concept was selected as having the greatest number of advantages for this design. Major airstream sensor elements are illustrated in Figure 15.

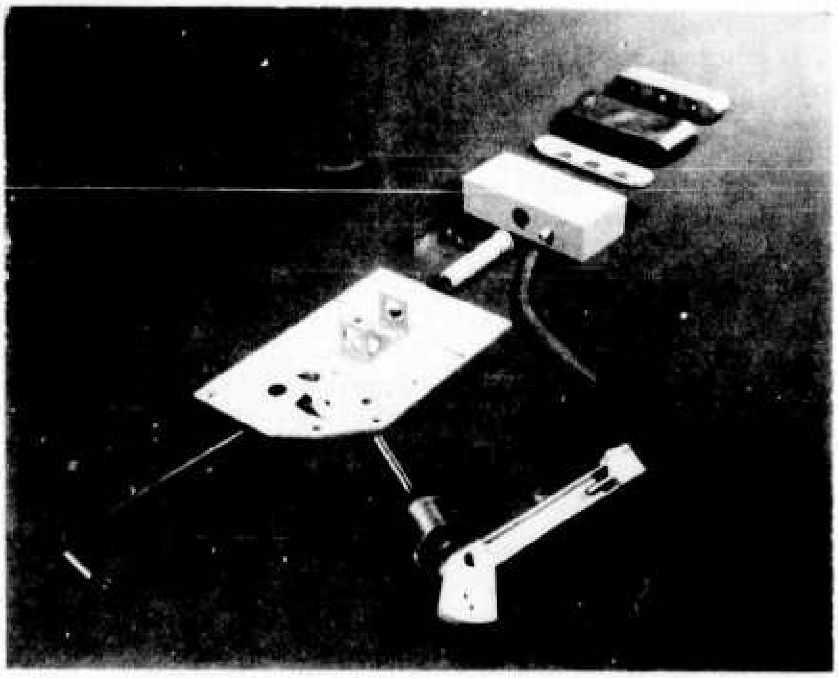


Figure 15. Airstream Environmental Sensor including Probe and Piston Elements

In the preactivated condition, the probe provides:

(a) Restriction of rotor rotation from the SAFE to ARM position
(b) Restriction of the piston shaft displacement from initial to full stroke position
(c) Retention of the thermal battery's spring-loaded striker pin in the full cocked position
(d) Pressure equalization across the opposing piston faces.

Erected by the stored energy of the helical drive spring, the probe extends into the imposed airstream to:

(a) Remove the rotor restriction
(b) Remove the piston shaft restriction
(c) Release the thermal battery's spring-loaded firing pin
(d) Receive ram air pressure associated with munition velocity.

The probe mechanism contains a cam profile that prevents explosive rotor movement from the SAFE position until the probe has been deployed. Figure 16 illustrates the amount of rotor rotation that can result for each degree of probe deployment.

Similarly, a pin located in the probe cam element intercepts the lock pin on the sensor's piston shaft to prevent translation unless probe deployment has taken place. Figure 16 describes the amount of piston shaft displacement as it relates to probe deployment angle. Rotor arming energy is a function of piston shaft stroke.

These features prevent premature activation when unintentional partial probe deployment occurs. Though not incorporated into the development models, the lock relationships can be employed to minimize prelaunch vibrational effects at the rotor and piston shaft through utilization of an elastic vibration isolation member.

As shown in Figures 4 and 5, the undeployed probe engages the battery striker lever to prevent battery initiation until sufficient probe rotation has occurred. The engagement interface is sufficient to prevent battery initiation whenever unintentional seal removal occurs or when supplementary electrical activation employed with long free flight munitions temporarily interrupts the probe's travel.

Air pressure equalization across opposing faces of the sensor assembly's piston element is accomplished by having both pressure pickup sources exposed to the common volume of the case interior.

The spring-loaded probe contains a bonded elastic vibration isolation material that bears against the undisturbed rectangular seal with sufficient area to prevent formation of localized stresses and case structure oil canning under vibration that could result in seal rupture.

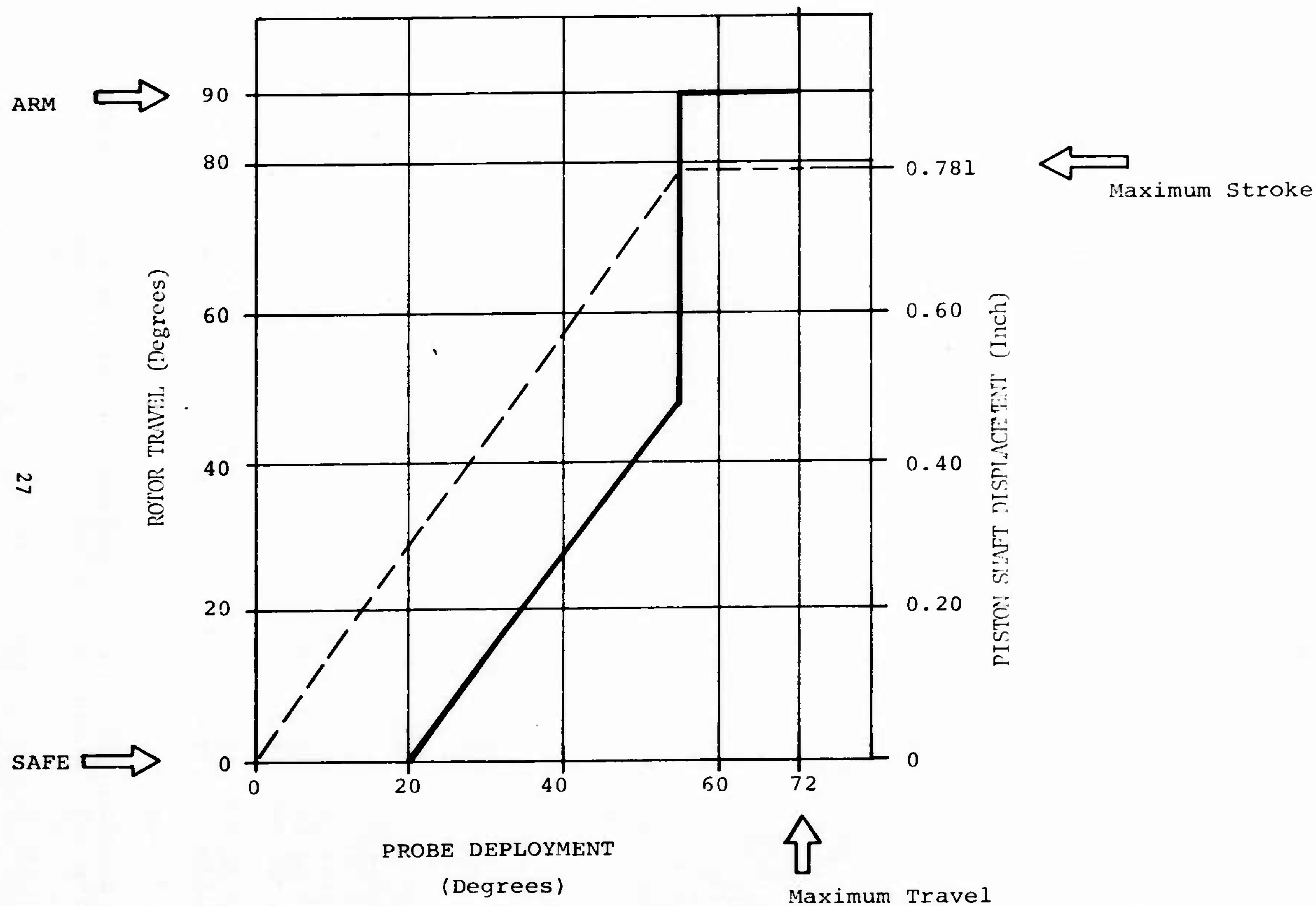


Figure 16. Approximate Restriction of Rotor Rotation and Piston Shaft Displacement by Degree of Probe Deployment

Probe deployment energy is provided by a torsional spring with sufficient power to deploy and maintain the probe in the maximum position. A simple spring clip locks the fully deployed probe in position.

The formed sheet metal probe contains an air shroud or duct that interfaces with the battery striker lever prior to deployment and provides a protective channel for airstream pressure pickup after deployment.

Direct conduction of the ram air pressure obtained at the extreme extension of a deployed probe to one side of the sensor's piston element is accomplished through a flexible tube or hose.

Aspiration or low air pressure source across the opposing piston face (which is open to the fuze interior) is obtained from the airstream passing over the exposed housing seal area bringing the fuze internal pressure to a corresponding value. It would be advantageous to physically isolate the probe from the electrical portions of the S&A to minimize environmental contamination, particularly when the supplementary electrical delay activation is employed.

The physical interfaces between the probe and the rotor, piston shaft plus battery striker, complicate the incorporation of a barrier or compartment. The principle of separating the sensitive electrical elements from the remaining subassemblies was not introduced into the development models. However, a simple cover over the rotor electrical switch assembly can be incorporated.

2.4.1 Probe Height

Probe extension above the projected munition superstructure is governed by the magnitude of the ram air pressure picked up at the probe's intake port. Air pressure magnitude is dependent, not only on flight velocity but on the air flow characteristics along the munition superstructure (i.e., the coning angle).

Based on previous pressure distribution data across typical munition profiles, Eglin AFB estimated that a minimum probe extension of 1.500 inches above the superstructure would be required. To compensate for perturbations in the normal angle of attack resulting from launch environment, a height of 2.625 inches above the superstructure was provided in the design.

Wind tunnel tests were not conducted because the influential munition configurations had not been established.

2.4.2 Air Pressure Sensor

Air pressure differential developed between the extreme probe pickup and the munition surface sources is utilized to

(a) Determine if the munition is operating within a free flight profile that exceeds the 150-knot minimum level

(b) Generate sufficient energy to drive the explosive rotor to the ARM position.

2.4.3 Airstream Pickup

The true differential pressure developed across the piston faces must be established by a series of wind tunnel tests utilizing the total munition. For purposes of this study, the theoretical pressure developed in an undisturbed airstream was used in the analytical study and the empirical experiments of the prototype units. Special probe and munition superstructure configurations which may modify the effects of the airstream were considered in this program.

2.4.4 Piston Output

To provide a sensitive responsive and low friction sensor element with maximum pressure face area for generation of significant force levels and a large stroke capacity for positive displacement and work output, a rolling diaphragm piston was selected.

G.E. SE 5211 Silicone rubber was selected as the material that could effectively operate over the full specified air velocity and environmental range. This particular material was successfully employed in several safing and arming designs.

The piston diaphragm originally developed for the MAU-116 unit was utilized in the DSA prototype design because its size closely conformed to the present DSA height requirements and it was available from present REI stores. Development of a new rectangular diaphragm configuration was not undertaken due to the long delivery required for the manufacture of a nonstandard unit.

The minimum force output capability of the piston assembly is therefore fixed by the diaphragm's effective area of 2.4675 square inches and the pressure developed at the minimum munition ALL-GO air velocity of 150 knots. Developing approximately 0.52 psi in an undisturbed airstream, the minimum force output of the piston assembly would be 1.28 pounds.

The potential energy output of the piston system increases proportionately with the increase in munition air velocity. However, in the DSA system, the piston reacts against the fixed resistive force presented by the arming energy storage mechanism and the system's friction. The application of greater pressure will only contribute to increased piston response.

At the maximum air velocity of Mach 2 (2175 ft/sec), a pressure of approximately 38 psi can be imposed on the diaphragm surface. Though this value does approach the burst level of the pure silicone MAU-116 diaphragm, the eventual addition of Dacron®

fabric to the diaphragm's fabrication process will increase its capacity to withstand higher pressures without any significant sacrifice in system performance. Successfully employed in the warhead S&A for the Navy's Harpoon, the process provided a burst level in excess of 190 psi.

Use of the existing MAU-116 diaphragm construction on the prototype DSA will limit the test input pressures to approximately 20 psi.

Figure 17 illustrates the analytical force relationship for the MAU-116 and DSA piston systems operating in a range of air velocity environments at sea level.

Though the piston force output at the lower specified ALL-GO air velocity limits was not sufficient to perform all necessary DSA functions under all imposed environments, the intent of the development models was to provide a vehicle from which future performance characteristics could be established.

2.4.5 Piston Anti-rotation

It was anticipated that some small piston shaft rotation would be developed from the design configuration's moment arms during the energy storage cycle. To counter these moments, early development models included provisions for the attachment of anti-rotational elements to the extreme internal flat surfaces of the rectangular piston. Tests indicated that the developed moment resultants were minimal and that they were adequately compensated for by the air pressure distribution within the diaphragm's convolution.

2.4.6 Piston

Transfer of the force and displacement developed by the piston to the velocity discrimination and arming energy storage element is accomplished through a translating piston shaft. For maximum efficiency, the piston shaft surface was dry lubricated to operate within a stainless steel bushing.

In the preactivated condition, the piston shaft is restrained from displacement by the interaction between its extended lock pin and the probe lock pin. Full probe deployment allows the piston shaft to displace when sufficient air pressure is applied across the piston faces (see Figure 16).

Anchored to and free to pivot about one plane along the shaft end opposite the piston, is one arm of a constant force compression spring.

2.4.7 Velocity Discrimination

As differential air pressures associated with imposed air

Based on MAU-116 Rectangular Diaphragm Having Effective Area of 2.4675 Square Inches

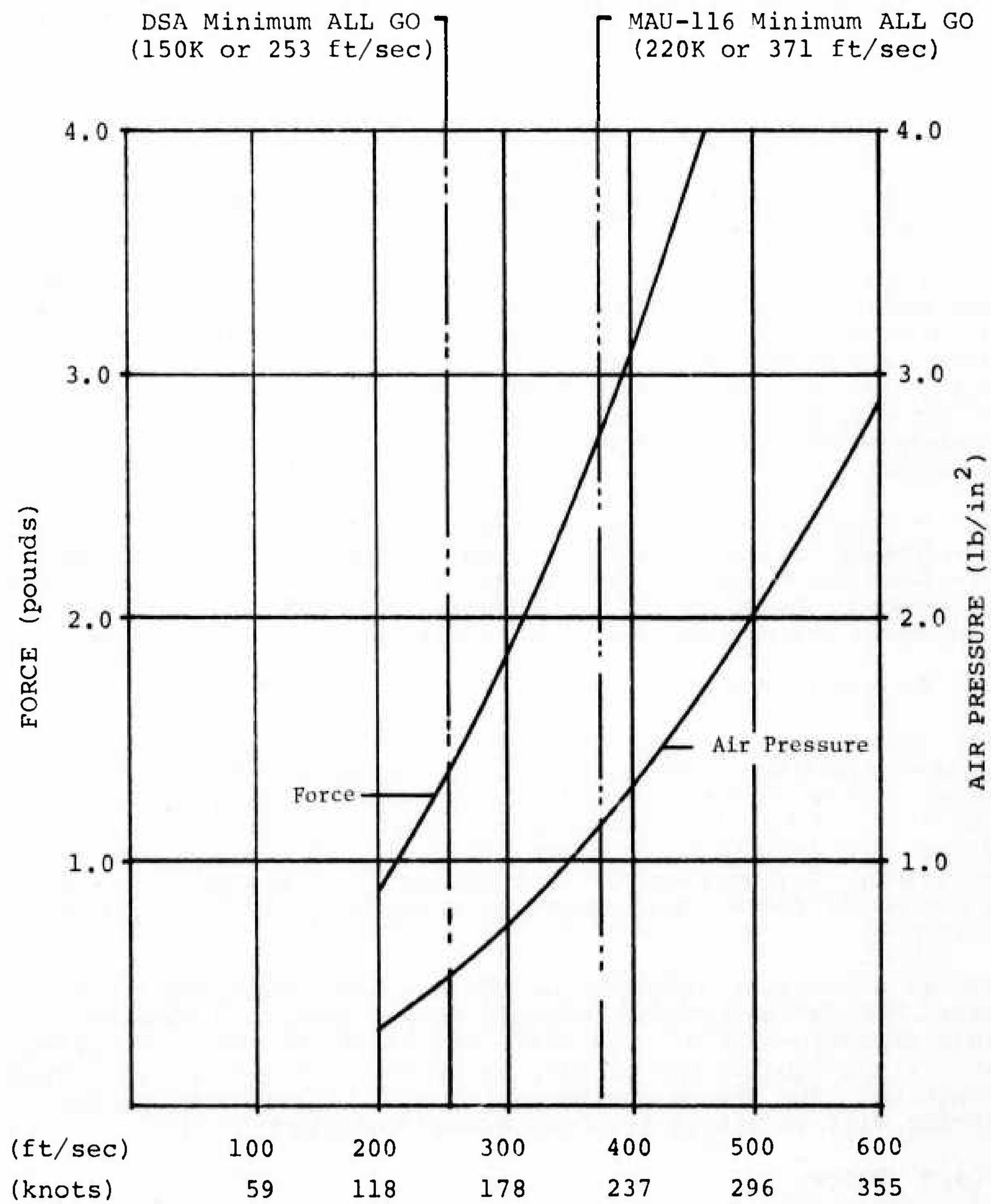


Figure 17. Airstream Velocity - Force Relationship at Sea Level

velocities acting on the system begin to influence piston motion, a resistance equal to the force generated at the minimum ALL-GO velocity must be overcome. This predetermined resistive force insures that the air piston will not move unless the generated force value is greater than the specified minimum ALL-GO equivalent force. The mechanism selected to accomplish this feature was a constant force compression spring. Characteristics of constant force (flection) compression springs are described in Figure 18.

Since the estimated pressure value for the minimum arm level is extremely low, the discrimination system has to be sensitive to a small pressure differential consistent with the effects of acceleration, shock and vibration on the mass of the piston assembly.

The mean discrimination value was chosen to lie midway between the specified maximum NO-GO and minimum ALL-GO air velocities with concentration on minimizing the tolerance bandwidth as much as possible and practical. Prior to the introduction of air pressure, the constant force compression spring is in a free state acting only as a mechanical link that contains no stored energy which would tend to move either element to which it is anchored toward an armed condition (see Figure 19(a)).

The constant force compression spring was designed to (a) provide the highest resistive force at its initial position, to obtain the selected threshold and breakover for discrete velocity discrimination purposes and (b) reduce its resistive load for the remaining system travel piston displacement (see Figure 18).

2.4.8 Arming Energy

The constant force compression spring serves a dual function. Once the maximum threshold force is overcome to provide airstream velocity discrimination, the reduced resistive force for the remaining piston stroke is employed to store sufficient force to drive the rotor element from the SAFE toward the ARM position. Movement to the full ARM position cannot occur until a series of system requirements are sequentially met (see Figures 2 and 3).

Should air velocity drop below the designated minimum ALL-GO level before the external electrical arm signal is applied (see paragraph 2.5.2), the force stored in the flection spring will react against the piston, returning it to the preinitiated position. The stored arming energy will be relieved and the spring will return to its free state condition.

2.4.9 Rotor

Anchoring the remaining spring arm to the rotor element permits the transfer and utilization of the constant force compression

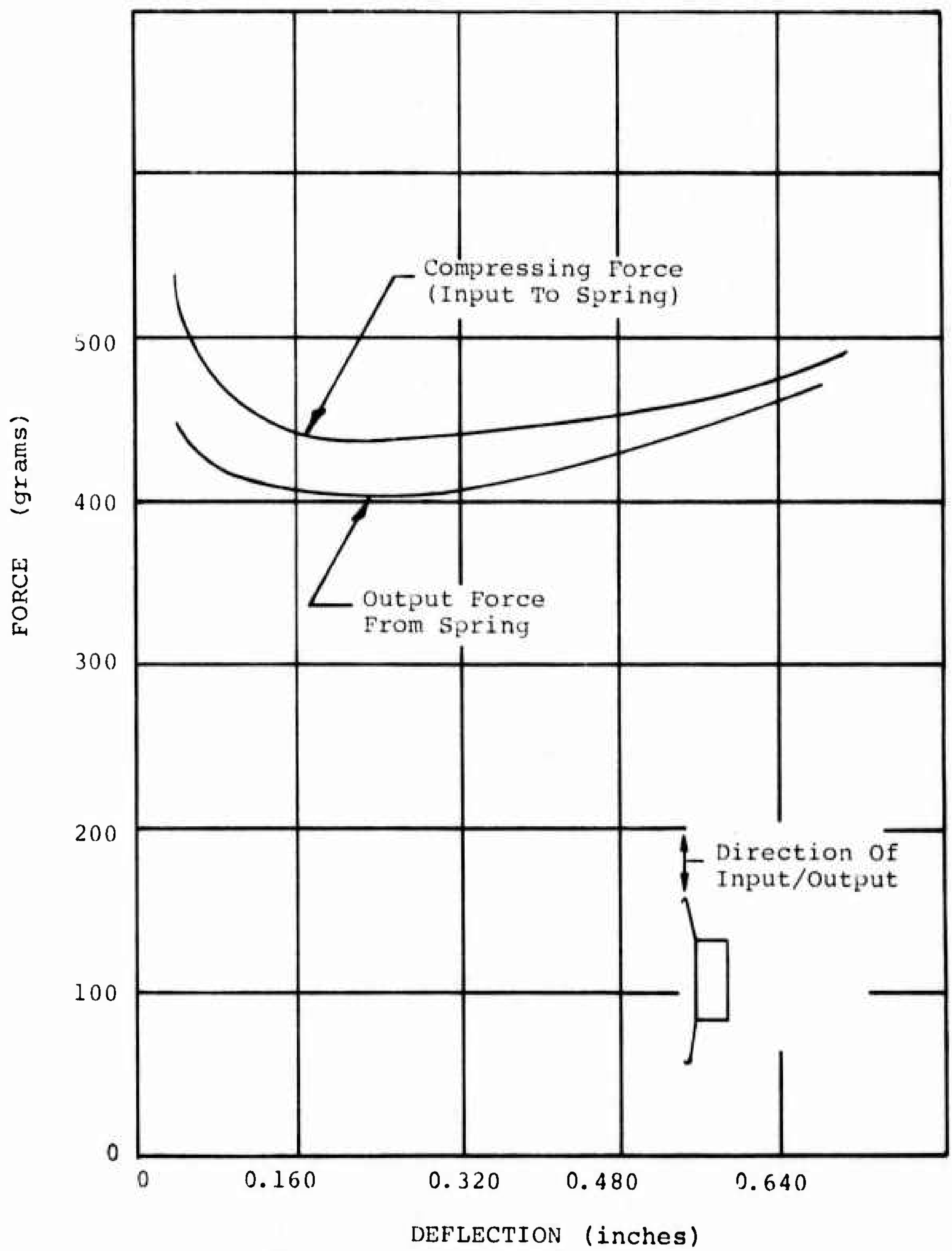


Figure 18. Flection Spring Force/Deflection

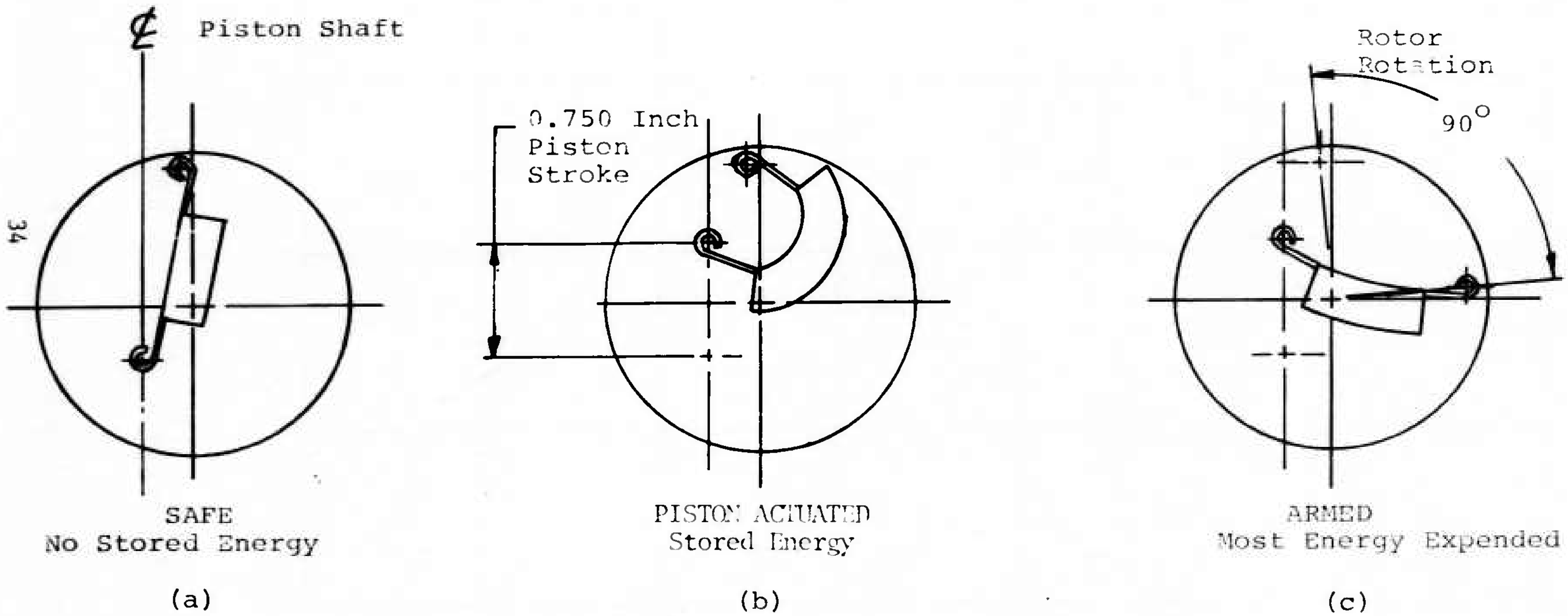


Figure 19. Arming Energy Level at Various Rotor Positions

spring's environmentally stored force and displacement characteristics to effect a 90-degree rotation from the SAFE to the ARM position (see Figure 20).

Locked in the SAFE position by the undeployed probe's profile during the prelaunch period, the freed rotor moves from the SAFE position (zero degrees) to the ARM condition (90 degrees) under the influence of the environmentally derived spring energy in three steps:

(1) 30 degrees of escapement-controlled rotation from the SAFE position (Figure 21).
(2) 15 degrees of free travel to the intermediate stop position (Figure 22).
(3) 45 degrees of free travel to the ARM position after release from the intermediate stop position (Figure 23).

The rotor is restricted at the intermediate position and locked in the ARM position by a spring-loaded electromagnetic actuator mechanism.

The yoke-like rotor structure shown in Figure 24 was based on the MAU-116 design that provided bearing support on each side of the arming spring's reaction force. Manufactured from aluminum and mass balanced, the rotor's functions are to position a MK9 lead from an out-of-line to an in-line explosive train status and an electrical detonator firing circuit from an open to a closed condition.

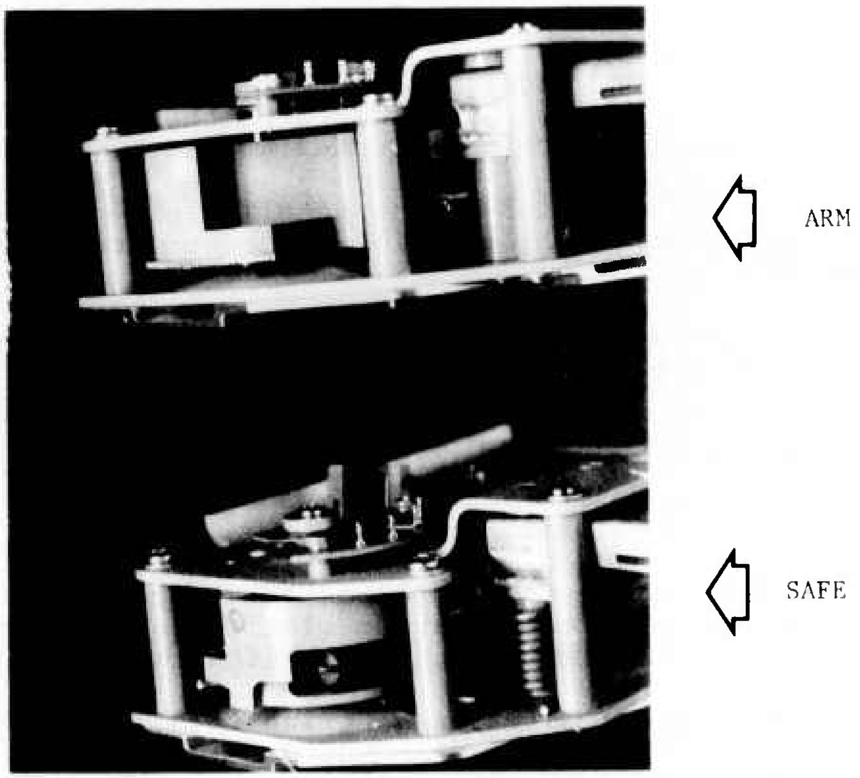
Arming drive torque is a function of the constant force compression spring's force characteristics and the available effective moment arm through which it acts (see Figure 25).

The rotor/piston-shaft/arming spring relationship which is identical to that employed in the MAU-116 system, creates forces that tend to positively lock the rotor toward the ARM position once the rotor has rotated beyond 68 degrees and the piston shaft is maintained in the full stroke position (see Figure 26).

2.4.10 Rotor Locks

In the preactivated condition, two locks retain the rotor in the safe condition - the undeployed probe profile's restriction as shown in Figure 5 and the primary rotor lock as illustrated in Figure 27(a).

After unit activation and probe deployment, the rotor remains locked in the SAFE position by the primary rotor lock until it is removed by the piston shaft's displacement. To provide an accurate and positive air velocity discrimination level and to prevent rotor movement until the piston shaft displacement is approximately 75 percent completed, the rotor lock illustrated



Side View

Figure 20. Rotor/Probe/Piston Shaft Relationships

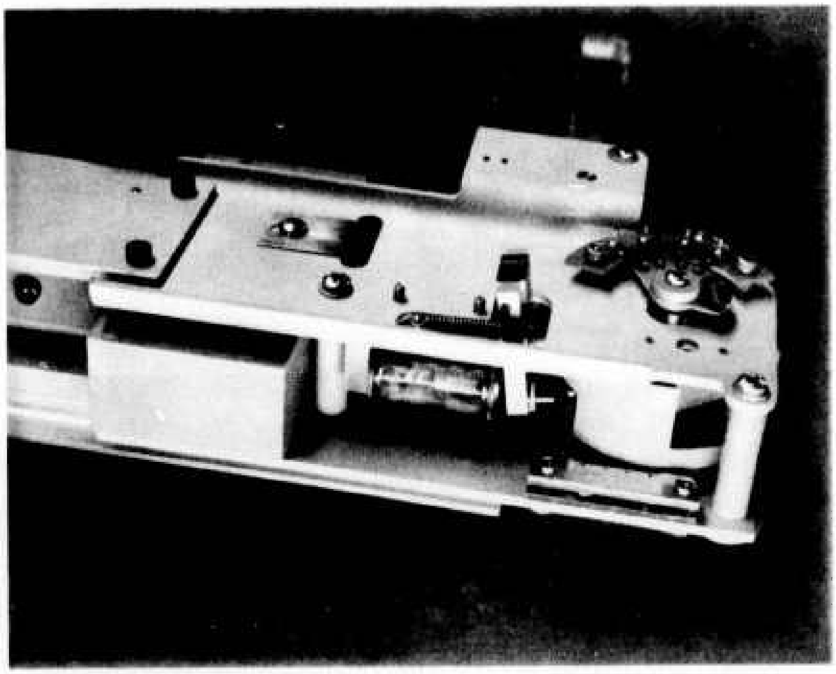


Figure 21. Safe Condition

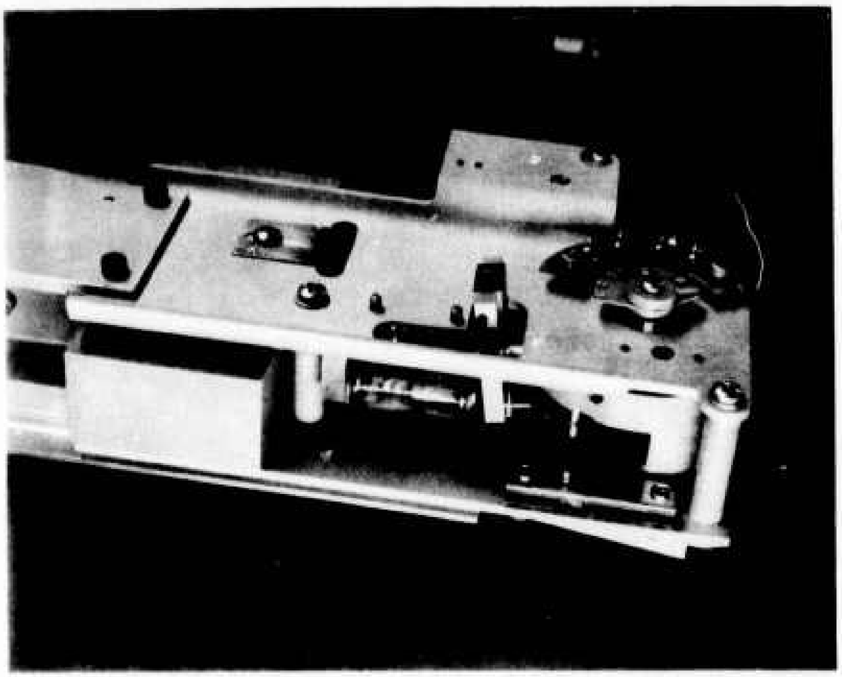
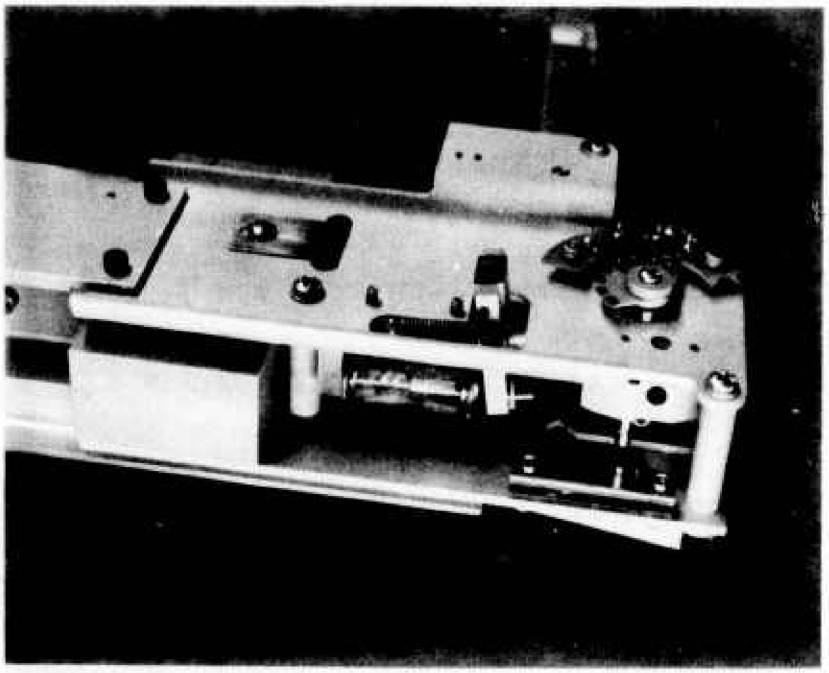
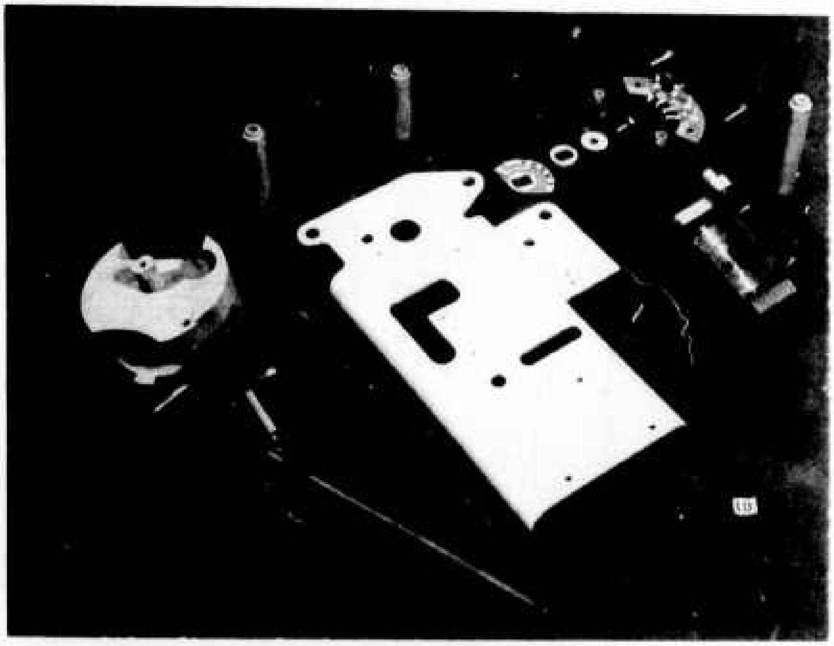


Figure 22. Intermediate Stop Position



Arm Condition

Figure 23. Rotor and Electromagnet Relationship



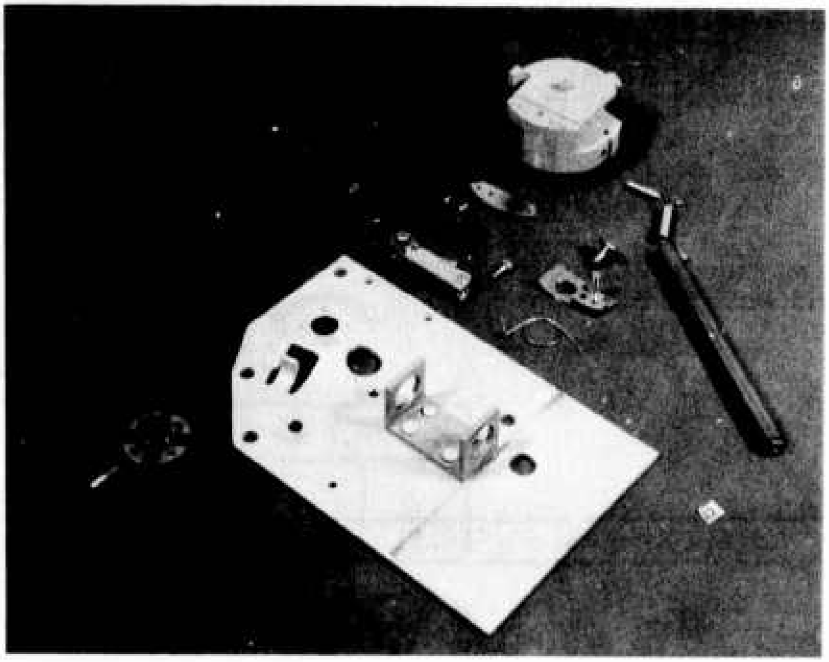
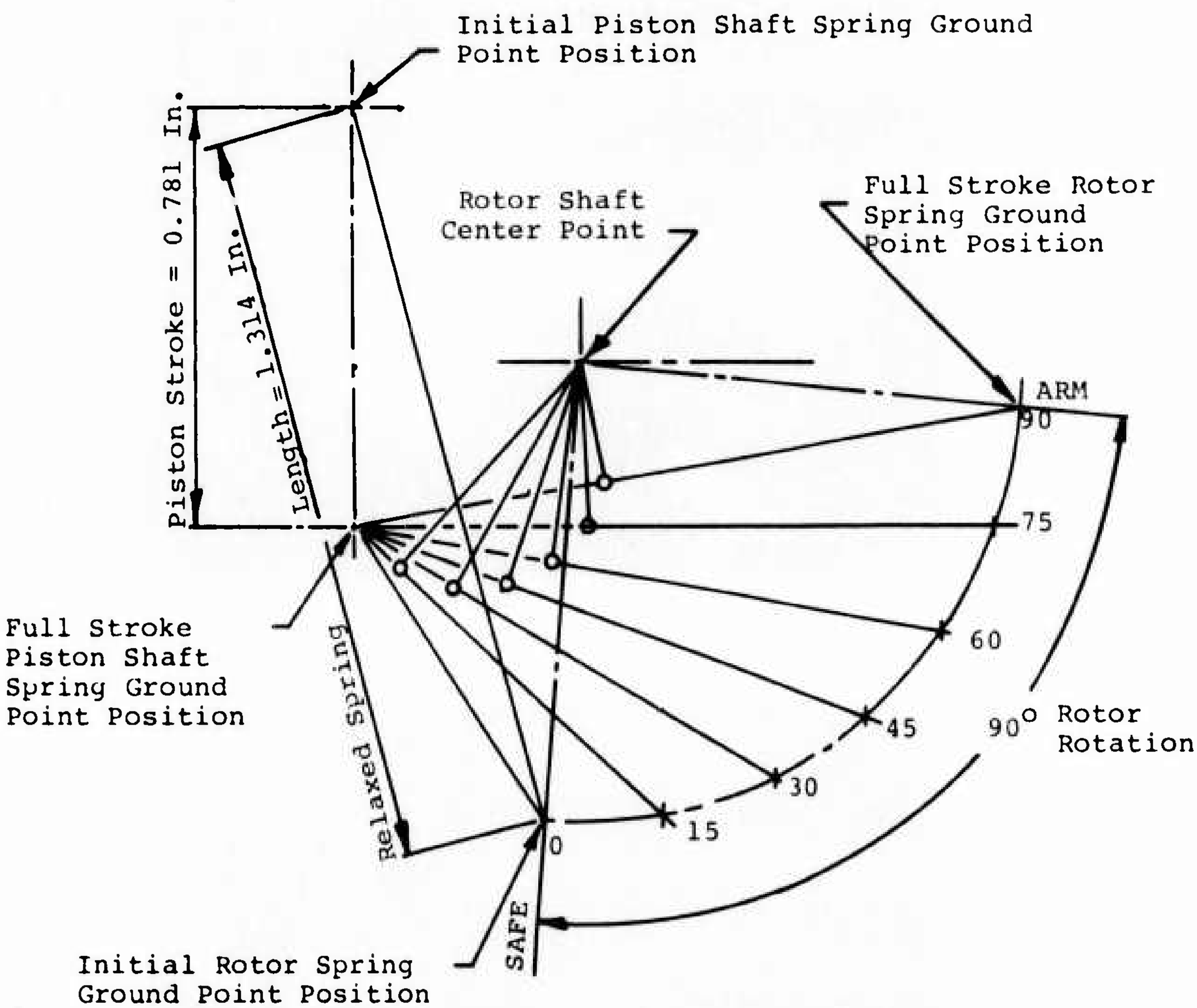


Figure 24. Rotor Interfacing Elements



	Rotor Rotation (Degrees)						
	0	15	30	45	60	75	90
Effective Moment Arm (Inch)	0.515	0.500	0.468	0.420	0.360	0.290	0.217

Figure 25. Rotor Drive Relationships

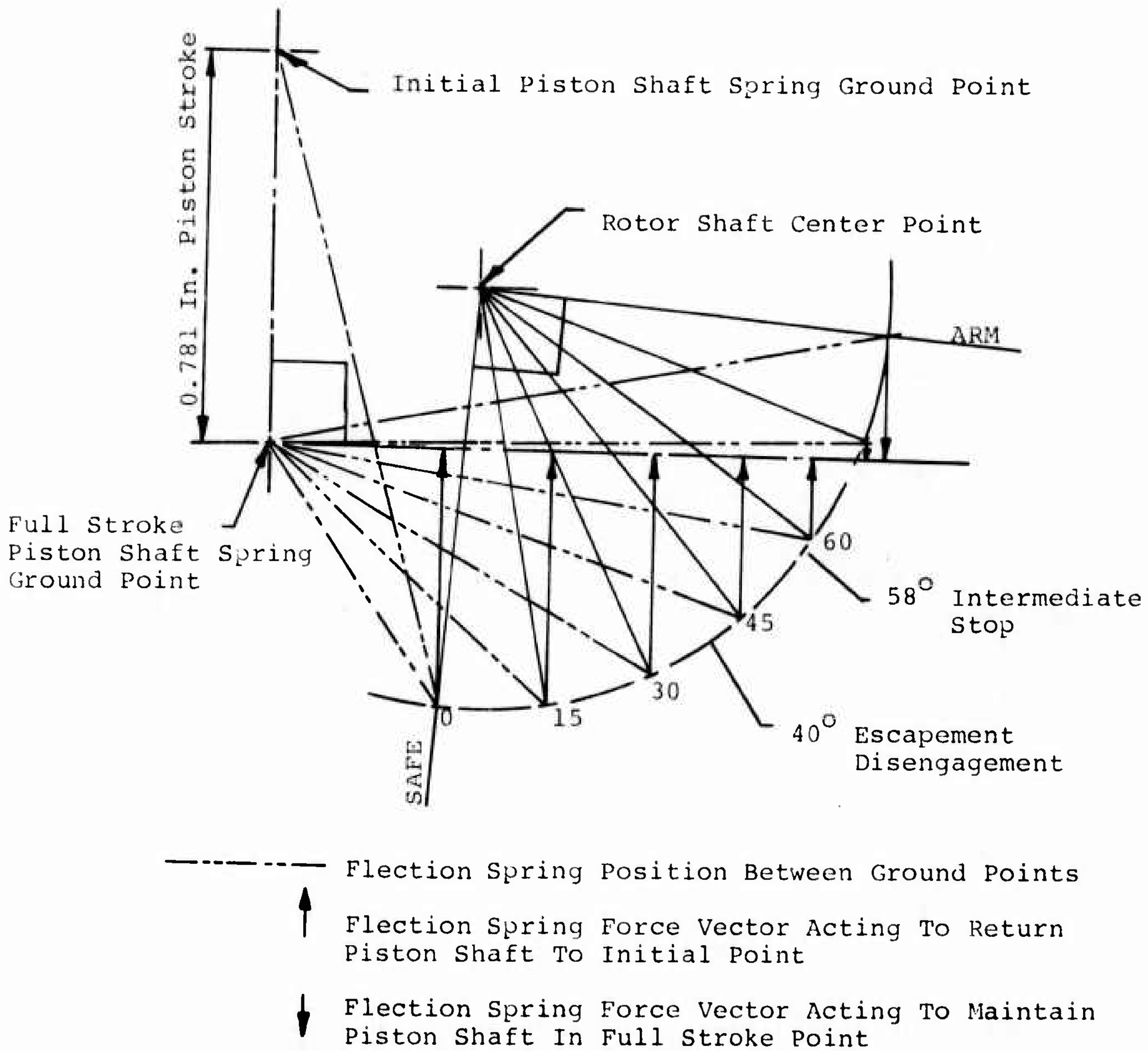


Figure 26. Rotor Drive Relationship With Piston Shaft at Full Stroke Position

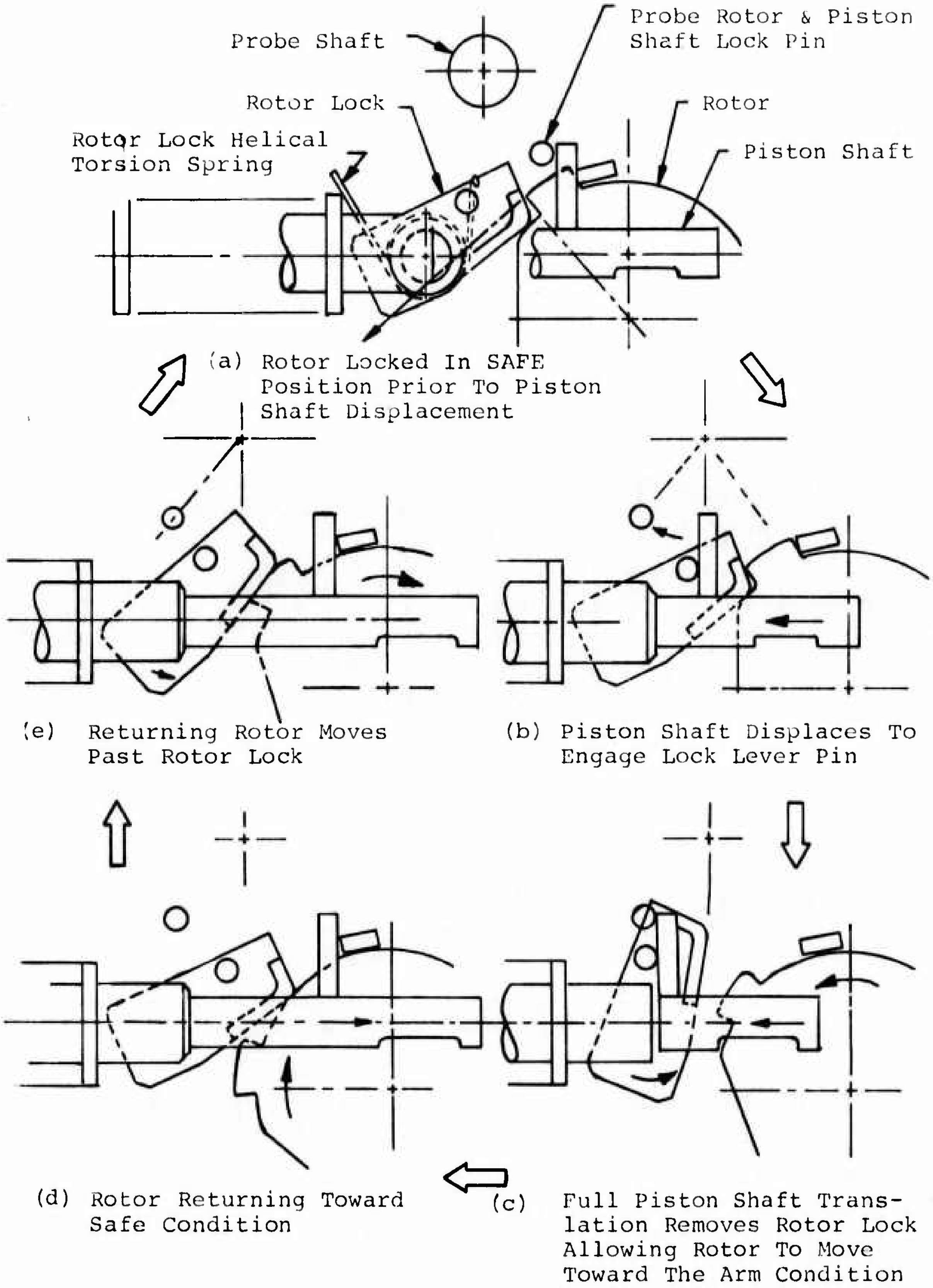


Figure 27. Rotor Lock Operation

in Figure 27 was incorporated. Providing minimal resistance to the discrimination level, the mass balanced rotor lock is designed to interact with the rotor to permit return to the SAFE position and relock.

2.5 SAFE SEPARATION TIME

Two independent safe separation time systems are employed.

(1) A mechanical escapement that controls the rotor's rotation during the initial arming period.
(2) An external electrical signal is received from the munition system to activate an electromagnetic mechanism that restricts the rotor's rotation beyond a fixed intermediate point.

Sequential initiation of both systems is necessary to promote rotor explosive train alignment.

2.5.1 Escapement

The MK330 escapement used in the MAU-116 was selected to provide the required delay time of 1.5 to 2.0 seconds for the prototype models.

Figure 28 describes the operational characteristics of the escapement mechanism with the selected combination of two 0.020-inch-thick aluminum pallets. Though this represents the most sensitive or most rapid escapement pallet combination for the minimal available input torque requirements, it also provides a greater degree of potential output time variation.

The DSA design incorporates a rotor drive gear segment equivalent to 152 teeth in 360 degrees which interfaces with the escapement to provide 30 degrees of escapement controlled rotor rotation, followed by a 15-degree free rotor travel before rotor travel is restricted by the electromagnet at the intermediate stop position.

Adjustment of the arming time will be accomplished through controlled variance of the counter return-to-safe spring torque output. An increase in the return-to-safe torque improves the rotor return characteristics. Modification of the rotor gear segment's leading gear tooth profile was introduced to increase the reliability of the segment's reengagement with the escapement's output pinion.

2.5.2 Electromagnetic Actuator

The purpose of the electromagnetic actuator is to provide a restriction of rotor rotation at an intermediate point and at the out-of-line position.

- Using the MAU-116 Logic Module & Timer Cam as the test fixture.
- Containing a pallet assembly with two (2) 0.020-inch-thick Aluminum Pallets
- Serial Number 1
- Temperature $72^{\circ}F$
- Torque required to overcome system inertia & friction = 0.06 in-oz

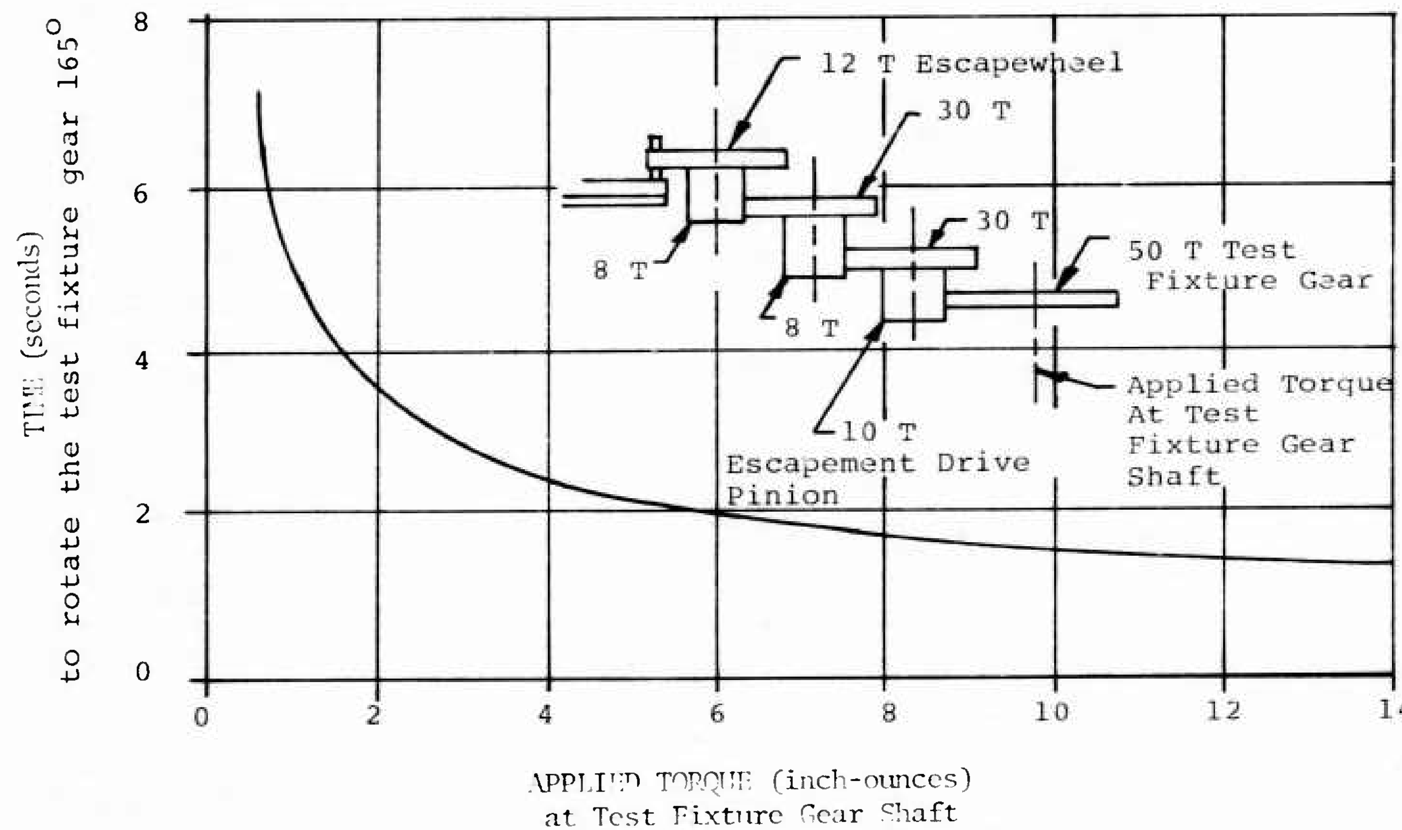


Figure 28. MK330 Escapement Operational Characteristics

Spring loaded to always intercept the rotor's path and provide rotor travel restriction, the electromagnetic actuator is initiated by an externally supplied electrical signal from the munition system.

The externally supplied signal originates from the target sensor's electronic timing device to provide the primary safe separation period. The signal is presettable and adjustable from 3 seconds minimum to a maximum of approximately 18 seconds. The electronic timer is not a component of the S&A. The secondary safe separation is provided by the mechanical escapement. This dual time capacity furnishes system safety against such incidents as a runaway escapement.

The electromagnet, which is designed to be normally open, is spring loaded to engage and restrict rotor travel to the full ARM position. Upon receipt of the electrical arm signal, the electromagnet will activate to release the spring-loaded rotor toward the full ARM position. Subsequent deenergization of the electromagnet will reengage the rotor profile and lock the rotor in the ARM position. To remove the ARM lock and allow the rotor to return toward the SAFE position, the electromagnet must be energized for approximately 1 second.

To provide a qualified MIL-STD electromagnetic actuator, the REI 1850 model illustrated in Figure 29 was introduced. The magnetic clapper element is mass balanced to prevent inadvertent activation during shock or vibration environment with a rotor interface that prevents self-locking relationships.

The requirements for "ELECTRICAL ARM", specified that a 7000 erg electrical signal will be available for activation of the intermediate stop mechanism. Though this is sufficient to activate an explosive element, it is insufficient to function an electromagnetic actuator operating under the imposed conditions.

An electromagnetic actuator was selected over an explosive device because of its recyclability feature.

2.5.3 Return Spring

The purpose of the rotor return spring is to insure that a free or detached rotor will be retained in the SAFE position and to provide a return force for normal system operation from any rotor position up to and including the electromagnetic stop location. With the rotor in the full ARM position, the spring provides the major reset force.

2.6 ELECTRICAL FIRING CIRCUIT

Keyed directly to and rotating with the rotor shaft, a flush double-sided printed circuit board is employed in combination

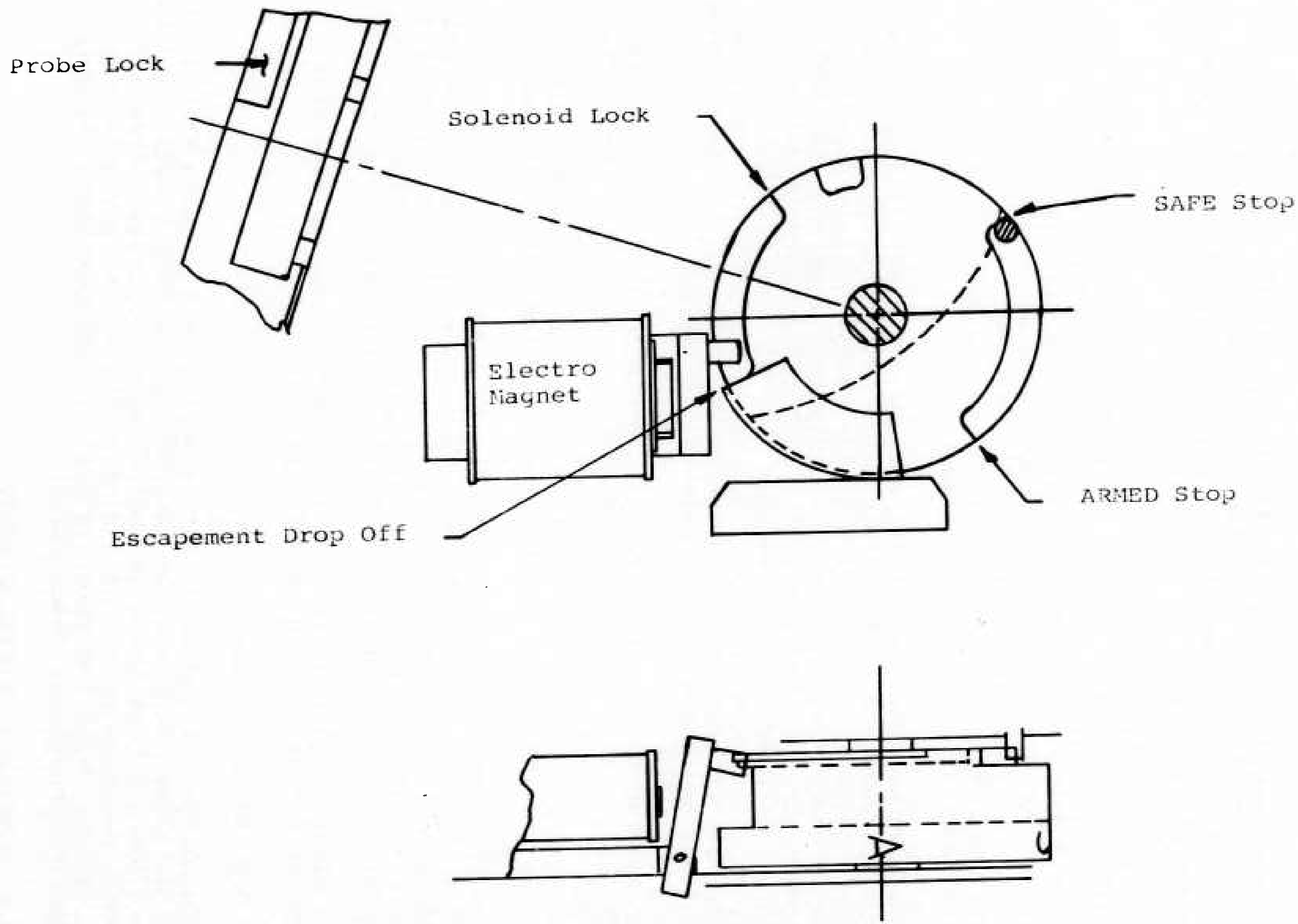


Figure 29. Electromagnet - Rotor Interface

with four pairs of REI contacts No. 1092-14 to establish an electrical firing circuit that provides:

(a) Independent initiation system ground
(b) Open detonator leads in the safe position
(c) Minimal static and dynamic frictional effects
(d) Maximum electrical characteristics
(e) Elimination of electrical feedback signals from the electromagnetic actuator's operation.

Figure 30 illustrates the DSA's circuit schematic.

2.7 BATTERY

A thermal battery provides all the electrical power normally required to initiate the DSA's explosive element and electromagnetic actuator plus furnish that power necessary to operate a mating electronic sensor. The battery is situated internally to the DSA case and mounted rigidly to the base plate. For applications with long flight munitions, an additional munition power source would be necessary to activate the DSA.

Advantages of mounting the battery internally are the elimination of seal as well as external electric wiring or connector interfaces. Disadvantages are the need for larger overall DSA case volume and the potential inflexibility of modifying the battery to provide greater power.

Sized to have the same output capacity as the thermal battery utilized in the FMU-110 electronic sensor, the battery is initiated by release of an integral spring-loaded primer striker that impacts against an M42 primer.

The battery striker is retained in the full cocked position by the undeployed probe structure. Probe deployment removes the striker restriction and the battery is initiated. Partial deployment which occurs during long free flight profiles results whenever the lanyard removes the seal and the external electrical delay mechanism intercepts the probe. Unintentional deployment occurs when the seal is accidentally fractured allowing the probe to deploy to the point where it strikes the taut lanyard of the unreleased munition. Under both circumstances, battery activation will be prevented.

Though live batteries were not employed in the development models, the inert elements did represent the volume required to provide electrical characteristics of an equivalent FMU-110 battery.

The munition's target sensor which receives electrical energy from the DSA's activated thermal battery transmits a firing signal back to the DSA whenever the target is sensed. If proper DSA arming functions have occurred, the electrical firing signal

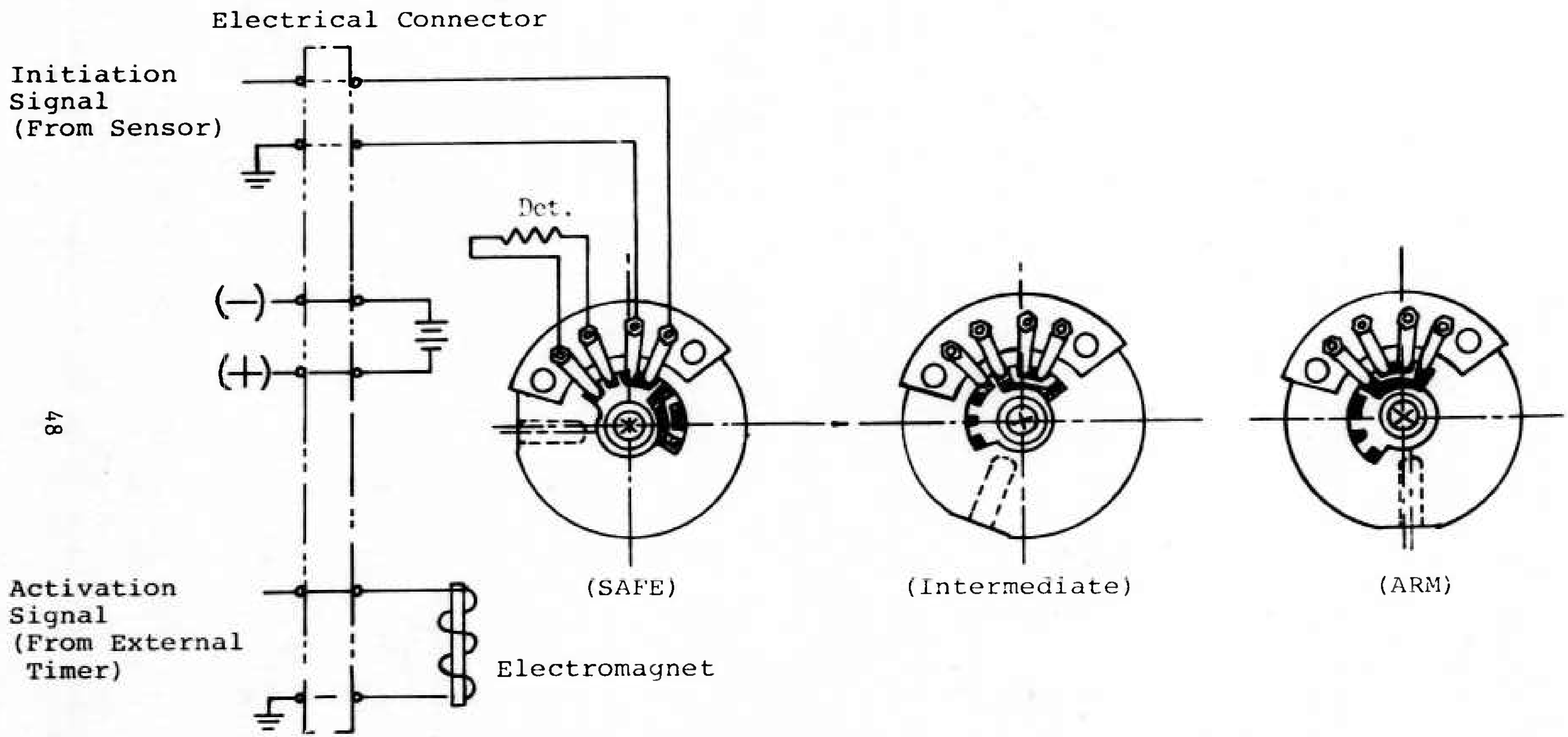


Figure 30. Electrical Circuit Schematic

will be conducted through the rotor switch circuit to the electrical detonator.

2.8 EXPLOSIVE TRAIN

The DSA explosive train consists of:

(a) One MK71 instant electrically initiated detonator mounted to the stationary plate structure
(b) One MK9 explosive lead staked into the rotor
(c) One MDF line attached to the external DSA case surface.

Figure 31 illustrates the out-of-line (SAFE) and in-line (ARM) relationship of the DSA explosive train.

The advantages of installing the detonator into the stationary frame are:

(a) A relatively safe rotor during assembly and testing which contains only a fairly insensitive lead.
(b) Easier assembly and soldering of detonator element with less need for critical clearances of rotating members.
(c) Improved detonator lead configuration
(d) Less complex rotor structure.

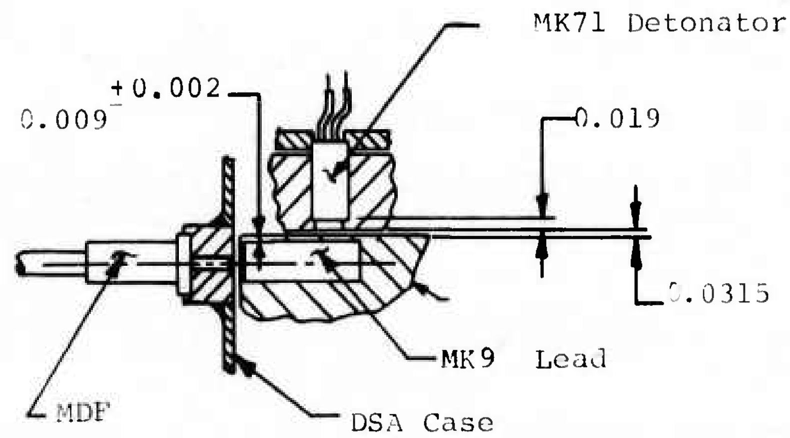
Reasons for providing a side explosive output are:

(a) Adaptability to various diameter munition bulkheads
(b) Employment of an integral probe which must be tangential to the munition's periphery
(c) Improved compatibility with various guidance and sensor packages.

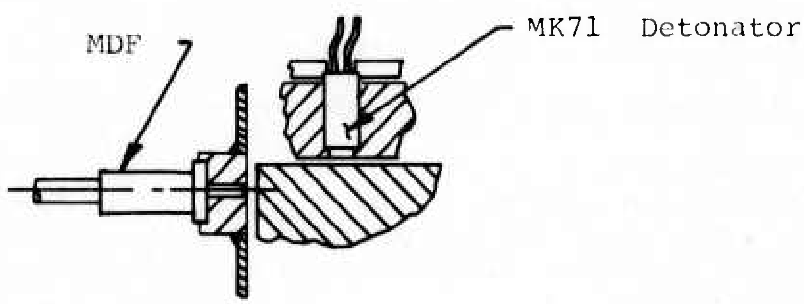
A large number of potential munition/S&A configuration combinations exist because of:

(a) A variance in munition bulkhead diameters
(b) A variety of explosive line locations along the munition bulkhead. Although the majority of the outputs will be located on the bulkhead centerline, some exceptions to the case, such as the SUU-54, will exist. The SUU-54 requires four outputs - 90 degrees apart - along the bulkhead periphery to initiate cutting charges.
(c) Various potential mounting configurations of the S&A.

For transfer of the output of the DSA's explosive train to the various bulkhead (explosive) configurations, Eglin AFB recommended the employment of the mild detonating fuze (MDF) line shown in Figure 31. The desirable feature of this product is its ability to form a flexible interface between a single or a series of explosive components.



In-Line Position



Out-Of-Line Position

Figure 31. Explosive Train Configuration

2.9 DSA OPERATIONAL CHARACTERISTICS

The following characteristics of individual DSA elements were empirically established from the two prototype models.

2.9.1 Deployment of Probe

The torques required to overcome the frictional resistance are:

(a) Deployment Lock - 0.14 in-lb
(b) Battery Firing Pin Striker Arm - 0.71 in-lb.

2.9.2 Battery - Striker Pin Spring

Torque generated with striker 90 degrees from the primer - 2.4 in-lb.

2.9.3 Tear Strip

Case Material - 110 Aluminum; condition zero; 0.040-inch thick.
Material thickness at the groove - 0.010 inch.
Groove Configuration - milled section with rounded inside edges to simulate formed process.
Pull Force required at 30 degrees vertical and 30 degrees horizontal line of action equals 45 pounds average, range of 41 to 48 pounds.

2.9.4 Electromagnet

Minimum actuation voltage	- 17 VDC
Air gap between clapper and coil	- 0.058 inch
Torque generated by electromagnet	- 8.97 in-lb (without influence of return spring output)

2.9.5 Return Mechanism Torque

Preactuated position	- 0.325 in-lb
Full stroke position	- 1.080 in-lb
Torque required to disengage electromagnet control arm at the intermediate stop position	- 0.07 in-oz

2.9.6 Piston (with diaphragm)

Forces required to translate piston shaft the full 0.781-inch stroke:

(a)	With stainless steel bushing and an aluminum Nituffed shaft	- 25 grams max
(b)	With an anodized aluminum bushing and a stainless steel shaft	- 25 grams max

2.9.7 Flection Spring Assembly

Force required to activate the piston/rotor system:

S/N 001	- 1.55 lb
S/N 002	- 1.60 lb

2.9.8 Rotor Assembly (with switch/contact assembly)

Torques required (without influence of safety return spring):

(a)	Maximum frictional drag rotating freely from SAFE to ARM	- 1.25 in-oz
(b)	At full SAFE position acting under influence of flection spring	-10.4 in-oz avg
(c)	At intermediate stop position acting under influence of flection spring	- 7.5 in-oz avg
(d)	At full ARM position acting under influence of flection spring	- 4.3 in-oz avg

2.9.9 Rotor Return Torsion Spring

Torque outputs measured at rotor shaft without influence of switch/contact assembly:

(a)	At SAFE (0 degrees) position	- 1.8 in-oz
(b)	At intermediate stop (58 degrees) position	- 2.2 in-oz
(c)	At ARM (90 degrees) position	- 2.4 in-oz

2.9.10 Escapement

Time for the rotor to travel through 40 degrees of controlled rotational arc and 18 degrees of free travel to the intermediate stop position with fully energized flection spring and against the return spring output - 2.1 sec avg

SECTION III

DSA DESIGN

3.1 SYSTEM FORCE BALANCE

3.1.1 Present Low Speed Requirement

The requirement of 150-knot ALL-GO system operation imposed a severe force reduction from the previously employed in the MAU-116 S&A. Using the same effective piston area of 2.4675 square inches, the available activation force is reduced from approximately 2.8 to 1.35 pounds. This force must:

(a) Drive the escapement
(b) Overcome switch contact friction
(c) Override the rotor return spring force
(d) Snap and hold the rotor in the arm position.

A capability of self-return of the rotor from the arm to the safe position when the piston pressure is removed and the eletro-mechanism is activated was introduced.

In the MAU-116, the spring force had to:

(a) Override plunger mechanism friction
(b) Overcome switch contact friction
(c) Snap and hold the rotor in the arm position.

The MAU-116 did not contain an automatic self-return rotor capability.

3.2 ROTOR CHARACTERISTICS

3.2.1 Rotor Return Force

A force acting directly on the rotor component to move it from the full ARM position back to the full SAFE position is provided by the rotor return spring. Identical to the return spring assembly employed on the FMU-109/B fuze, the torque output of the return spring was modified to meet system requirements. The present design provides approximately 2.4 in-oz of return torque capacity at the ARM position with 1.8 in-oz of resistive torque provided at the SAFE position.

Under operational conditions, this torque must be employed to overcome the resistance generated by the switch contact assembly, the escapement and the rotor bearing surfaces.

3.2.2 Arm Condition

When an activated in-flight fuze system has reached the ARM position, the rotor is maintained and locked in that position by two conditions.

(1) The fully energized piston assembly acts on the flection spring to maintain a force output which retains the rotor against the stationary ARM stop surface.

(2) The entrapment of the rotor between the electromagnet assembly's control lever and the stationary ARM stop surface.

3.2.3 Preventive Forces

The subsequent removal of both the air pressure from the piston assembly and the lever restriction of the rotor will not create a condition in which the balance of remaining forces is capable of returning the rotor to the full SAFE position. Conditions which exist to prevent this return are:

(a) In the arm condition, the physical relationship of the activated piston shaft spring ground point, the rotor ground point and the rotor rotational axis are identical to the MAU-116 system in which the flection spring force reacted to maintain the piston shaft and the rotor against the full ARM position stops. When the rotor is positioned anywhere along an arc of travel of 20 degrees from the ARM condition (70 degrees from the SAFE condition) the tendency (force balance) is for the rotor to remain in or move toward the full ARM condition (see Figures 25 and 26).

(b) There are no independent forces operating on the piston shaft which will act to return the piston assembly to the unactivated or SAFE position. The function of the bias spring in the FMU-109/B unit is to return the piston when all actuation and locking forces are removed.

(c) In a RETURN TO SAFE condition, the flection spring acts as a loose link between the rotor and piston shaft having no stored energy to influence the relationship of either element, only when the rotor is located 45 degrees from the SAFE position. This condition is similar to that of the FMU-109/B.

(d) The low pressure associated with the minimum specified ALL-GO level and the use of the MAU-116 diaphragm (fixed effective area) restricts the total amount of force that can be developed to overcome the flection spring threshold level and store energy for arming. The available energy limits the amount of torque output that can be allocated to the rotor return spring.

(e) Once the rotor has rotated to the full ARM condition, the electromagnet stop lever locks the rotor in place. During normal launch sequence, the signal to activate the electromagnet (which allows rotor travel from the intermediate stop position to the full ARM position) originates from the target sensor timer. An auxiliary signal to the electromagnet would have to be employed to remove the full ARM lock condition.

(f) Reengagement of the escapement gear train once the rotor has traveled beyond the rate controlled condition.

3.2.4 Rotor System Functions

The normal characteristics of the individual components of the present design as the unit operates from a full SAFE to a full ARM condition are described in Figure 32. The ARM to SAFE characteristics are described in Figure 33.

3.2.5 Rotor Recyclability

To effectively return the rotor from the full ARM to the full SAFE position, the following actions must occur.

(a) <u>ARM Stop</u> - Removal of the electromagnet control lever restriction to allow rotor balance of forces to move the rotor toward the SAFE position.

(b) <u>Rotor Stop/Control Lever Interface</u> - The signal for the withdrawal of the electromagnet control lever restriction (item a) must be maintained for a long enough period to allow the rotor to travel approximately 32 degrees from the ARM position. This will insure that frictional drag between the two elements will not influence the return process.

(c) <u>Piston Shaft</u> - The piston shaft is independently returned to its original preactivated position to prevent the flection spring, which is acting as a link, from interfering with or resisting rotor movement (See Figure 34).

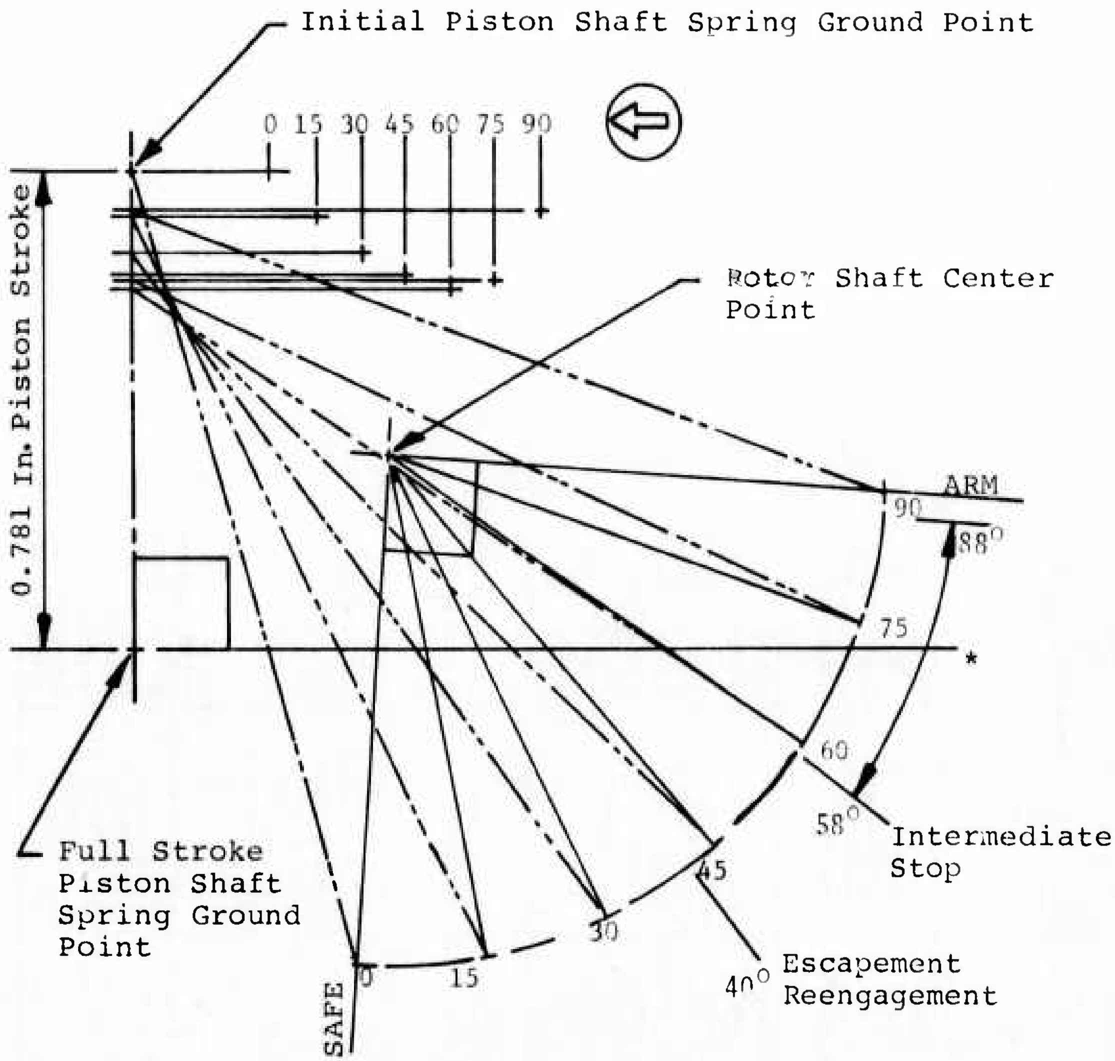
The piston shaft return force also acts directly on the rotor to promote the return-to-SAFE feature. If differential air pressure is removed from the piston when the piston shaft is fully activated and the rotor is in the full ARM position, an independently spring-loaded piston shaft travels approximately 0.1875 inch before striking the fully ARMED rotor. The return spring force acts on the rotor at an effective lever arm of approximately 0.562 inch to assist the rotor return-to-SAFE feature for approximately 50 degrees of the rotor's travel from ARM. Additional assistance at a reduced torgue arm will be available for the next 30 degrees. At this point, the piston shaft travel terminates and the rotor return spring

Explosively Loaded Rotor System Status	RESTRICTION		ENERGY SOURCE	ARMING FORCE	DRIVEN	RATE CONTROL	SAFING DRIVE
	1 PROBE	2 ELECTROMAGNET STOP LEVER	3 PISTON SHAFT	4 FLECTION SPRING	5 ROTOR	6 ESCAPEMENT	7 RETURN SPRING
A Safe Position 0 Degrees	Undeployed - locking rotor and piston shaft in unactuated position.	Inactive - spring loaded stop lever held in rotor intercept position at the intermediate stop location.	Inactive - restricted from moving to the activated position by the undeployed probe.	Inactive - no stored energy.	Inactive - locked by probe and engaged with escapement. Maintained against SAFE stop by return spring. No energy imposed tending to ARM.	Inactive - engages rotor gear.	Active - providing torque to maintain rotor in safe position.
B Arming Delay 0 to 40 Degrees	Deployed restriction of rotor and piston shaft removed.	⇩	ACTIVE - probe restriction removed. Piston assembly responds to differential air pressure created by flight velocity.	ACTIVATED - Energy stored by displacement of piston shaft drives rotor toward ARM condition.	Active - unrestricted moving toward ARM position under influence of flection spring energy with rotational rate controlled by escapement.	Active - engaged to rotor to control rotational rate. Being driven by flection spring force.	Active - output being overcome by arming torque developed by flection spring.
C Free Travel to Intermediate Stop 40 to 58 Degrees	⇩	⇩	⇩	⇩	Active - disengaged from escapement - moving toward ARM position under influence of flection spring energy.	Inactive - disengaged from rotor gear.	Output increases proportional to rotor proximity to ARM position.
D Intermediate Stop position (SAFE side) 58 Degrees	⇩	Inactive - restricts further movement of rotor toward the ARM position.	⇩	⇩	Inactive - restricted from further rotation by stop lever held toward ARM position by influence of flection spring energy.	⇩	⇩
E Free travel to ARM position 58 to 90 Degrees.	⇩	Activated by 200 millisecond long electrical pulse from seeker timer to electromagnet removing restriction of rotor.	⇩	⇩	Active - released by stop lever to rotate toward ARM under influence of flection spring energy.	⇩	⇩
F ARM position 90 Degrees	⇩	Inactivated - captivates rotor and restricts movement toward SAFE position.	⇩	Activated - stored energy continues to drive rotor against stop.	Inactive - restricted by stop lever from returning toward SAFE. Held toward ARM by flection spring energy. Return spring acting toward SAFE position.	⇩	Maximum output torque tending to drive rotor toward SAFE position.

Figure 32. Rotor Drive and Control SAFE to ARM Characteristics

Explosively Loaded Rotor System Status	RESTRICTION		ENERGY SOURCE	ARMING FORCE	DRIVEN	RATE CONTROL	SAFING DRIVE
	(1) PROBE	(2) ELECTROMAGNET STOP LEVER	(3) PISTON SHAFT	(4) FLECTION SPRING	(5) ROTOR	(6) ESCAPEMENT	(7) RETURN SPRING
(A) Safe Position 0 Degrees	↑	↑	↑	↑	Inactive - maintained against SAFE stop by return spring - engaged with escapement.	Inactive - continues engagement with rotor gear.	Active - providing torque to maintain rotor against stop in SAFE position.
(B) Escapement Controlled Rotation 40 to 0 Degrees	↑	Inactive - spring loaded to return to intercept position but presents no interference with rotor to SAFE	Open end contact terminated at approx. 20 degrees from SAFE	Inactive - relationship of piston shaft and rotor ground changed to release stored energy.	Active - output torque of return spring operating through escapement to rotate rotor toward SAFE.	Active - rotor gear engages escapement pinion - critical tooth profile mating situation.	↑
(C) Free Travel to the Rotor Gear Engagement of Escapement Pinion. 58 to 40 Degrees	↑	Must be actuated to remove rotor restriction and allow movement toward SAFE. Lever must remain retracted for 30° of rotor travel toward ARM to avoid influence of lever stop pin riding on rotor profile.	Must be returned manually toward SAFE. Open end contacts rotor surface to assist rotor return to SAFE	ACTIVE to approx. 45 degrees from Safe. Becomes INACTIVE at 45 degrees once relationship of piston shaft and rotor grounds are changed to release stored energy.	Active - moving toward SAFE under influence of return spring output after 45 degrees. Must be manually assisted from 88 to 45 degrees.	↑	↑
(D) Intermediate Stop Position (ARM Side) 58 Degrees	↑	↑	Open end resting against rotor	↑	INACTIVE - stop lever restricts rotation toward SAFE. Flection spring output toward ARM.	↑	Output torque decrease proportional to rotor proximity to safe position.
(E) Free Travel to ARM side of Intermediate Stop, 90 to 58 Degrees	↑	↑	Must be returned toward SAFE manually, is capable of moving approx. 0.1875 inch of full 0.781-inch stroke before striking ARMED rotor body	Slight rotational rotor movement will have insignificant effect on force output toward ARM.	ACTIVE - moving toward SAFE under influence of return spring output and manual assistance. Slight rotation allowed by tolerance buildup.	↑	Output torque capable of overcoming frictional resistance of rotor bearings and electrical switch but insufficient to overcome flection spring output.
(F) ARM Position 90 Degrees	Deployed - restriction of rotor and piston shaft removed	Inactive - captivates rotor and restricts movement toward SAFE position.	Inert - differential air pressure created by flight velocity diminished below minimum level. Probe restriction removed.	ACTIVE - relationship of piston shaft and rotor ground points provide residual force to maintain rotor against ARM stop and piston fully activated.	INACTIVE - restricted by stop lever. Return spring output acting toward SAFE. Flection spring output acting toward ARM.	INACTIVE - disengaged from rotor gear.	ACTIVE - providing maximum torque toward SAFE.

Figure 33. ARM to SAFE Characteristics



* Potential Arc Of Electromagnet Control Lever Pin And Rotor Stop Profile Interface Creating Frictional Drag.

Figure 34. Arming Spring Ground Point Positions

output supplies the energy required to return the rotor the remaining 10 degrees to the full SAFE position (see Figure 35).

3.3 PISTON RETURN FORCE

Using a Teflon® lubricated shaft operating in a stainless steel bushing, the measured constant drag force required to return the piston assembly from full actuated to the original preactuated position is 0.91 ounce (25 grams) or 0.051 pound.

A 3 ounce minimum piston shaft return spring force at the pre-actuated position provides the energy required to effectively return the piston shaft under all conditions.

3.4 RECYCLABILITY - TOTAL ALL-UP UNIT

The DSA design does not have a self-recyclable feature because of these major reasons:

(a) Tear Strip - activation of the unit is initiated when the case tear tab is removed by lanyard force. A new case is required for each initiation.

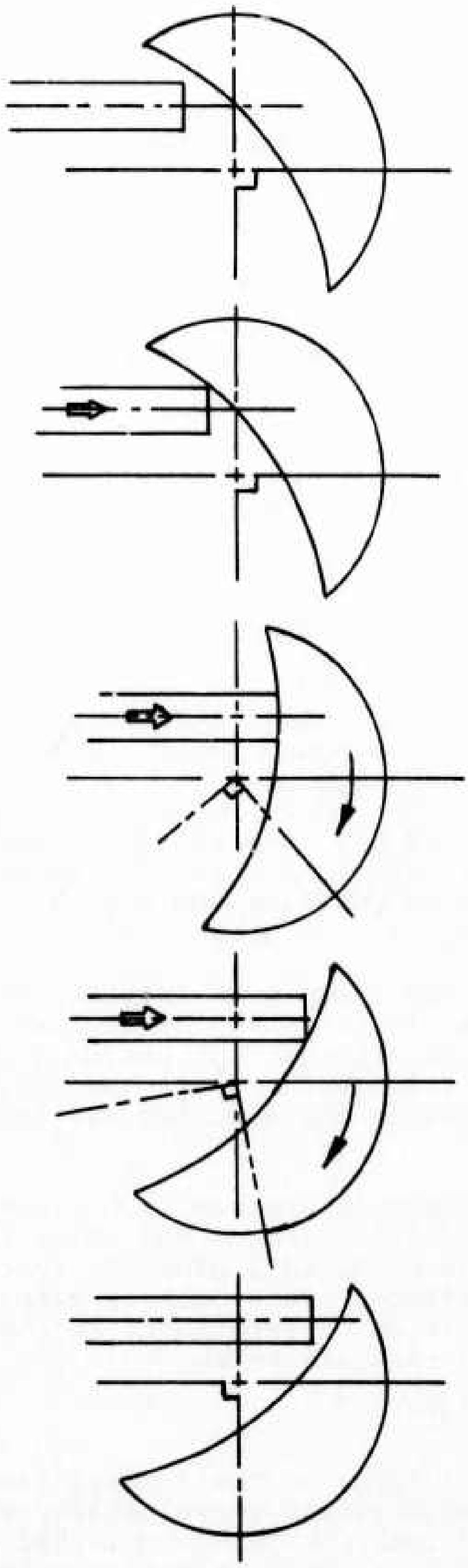
(b) Probe - The spring-loaded probe projects above the munition structure when the tear tab restriction is removed. The probe locks in the extended position and must be manually unlocked and returned to the prelaunch location.

(c) Battery - The deployment of the probe will initiate the thermal battery whose purpose is to supply electrical power to the target sensor and through that sensor system the actuation signal to the DSA electromagnet and the firing signal to the DSA electrically actuated explosive detonator.

(d) Rotor Arm Lock - In normal arming operation, the electromagnet control lever is employed to secure the rotor in the arm position after it has provided a blocking function at the intermediate stop position. This lock is normally maintained to the end of cycle which terminates in the initiation of the explosive train elements.

3.5 RECYCLABILITY - PRESEALED UNIT

In the presealed state, prior to joining of the forward case (which contains the tear strip feature) the recyclability of the probe, battery, and rotor arm lock can be accomplished as follows: The probe and rotor arm lock can be manually unlocked and reset while the activation of the battery can be locked by insertion of a safing pin.



A. Rotor in ARM and Piston Shaft fully actuated.

B. Rotor in ARM with Piston Shaft returning toward preactuated position.

C. Rotor 50 degrees from ARM with Piston Shaft returning toward preactuated position.

D. Rotor 80 degrees from ARM with Piston Shaft at full preactuated position.

E. Rotor at SAFE with Piston Shaft at full preactuated position.

Figure 35. Influence of Spring-loaded Piston Shaft on Rotor Return Capability

SECTION IV

DEVELOPMENT TEST RESULTS

4.1 TEST SEQUENCE

The development test series was selected to subject the two prototype DSA devices to the more critical environments and to assess the effects of those environments on unit characteristics and performance. The small quantity of devices did not permit full evaluation of the design, or the generation of statistical data.

The scheduled sequence of engineering evaluation tests were supplemented by additional runs to obtain further or confirming data as illustrated in Table 2.

Figure 36 shows the two DSA units as mounted during the various vibration tests.

4.2 TEST RESULTS

Results of all tests (except the Safety Series) are compiled and given on Table 3. A review of these results shows the following highlights.

4.2.1 Acceptance Test

Both units showed actuation levels between 0.80 (NO-GO) and 0.85 (ALL-GO) pressure differentials. Both had arming times of 3.3 seconds, and reset when arming pressure was removed.

4.2.2 Transportation Vibration (S/N 0001)

Caused the unit's actuation level to increase slightly and the times to change (both faster and slower). The unit reset after actuation.

4.2.3 Random Vibration

Both units again showed an increase in actuation level. Times varied within a generally predictable envelope. Units reset in all cases.

In one test, the tear strip failed (see Figure 37), providing an unplanned confirmation of the safety system, in that the probe did not erect sufficiently to remove its restriction of the rotor when case tear strip failure occurred.

In the current design, the spring-loaded probe bears, via an elastic vibration dampening element, against a portion of the

TABLE 2. DEVELOPMENT TEST SEQUENCE

	Test Number	
	S/N 0001	S/N 0002
A. Acceptance Test		
No Go Level	1	A
All Go Level	2	B
B. Handling and Storage Series		
Transportation Vibration	3-5	--
Thermal Shock	6-7	---
C. Carriage and Launch Series		
Random Vibration	8-18	C-N
Low Temperature	19-21	---
Ambient Temperature	22-26	---
High Temperature	27-31	0
Ambient Temperature	32-34	P-U
Low Temperature	35-36	V-X
Ambient Temperature	37-41	Y-AD
D. Safety Series		
Five Foot Drop	X	---
Static Detonator Safety	X	---

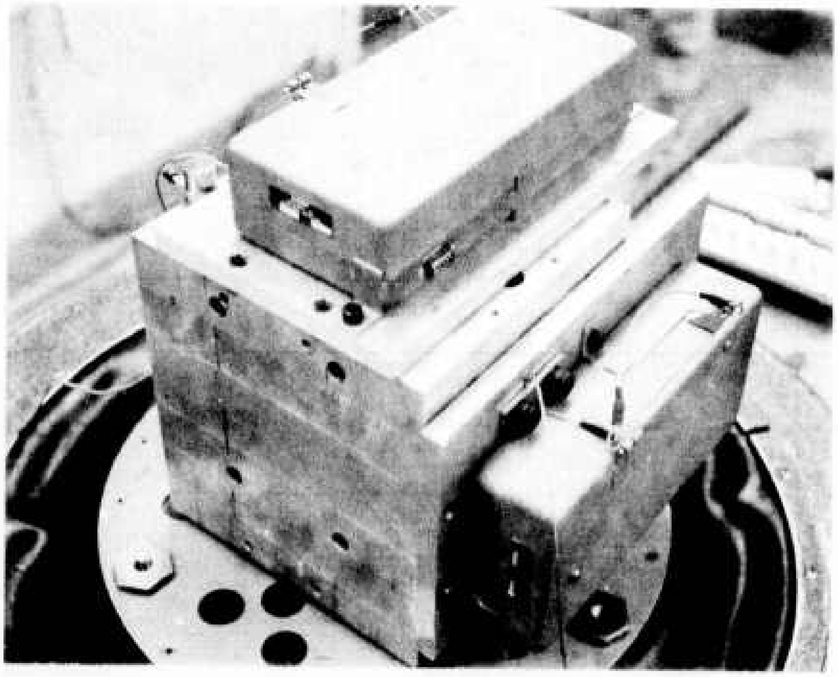


Figure 36. Vibration Test Fixture

TABLE 3. TEST RESULTS

	PSI				Time (Seconds)		Volt		Solenoid Resistance		Detonator Resistance		Reset		Comment
	Run	S/N 1	Run	S/N 2	S/N 1	S/N 2	S/N 1	S/N 2	S/N 1	S/N 2	S/N 1	S/N 2	S/N 1	S/N 2	
Accept	1	0.80	A	.80	N.G.	N.G.							None	None	
	2	0.85	B	.85	3.3	3.3	17	15	22.3	22.3	5.41	5.31	Yes	Yes	
Trans-	3	0.925			4.7		15		22.2		5.54		Yes		
portation	4	0.95			3.0								Yes		
Vibration	5	0.88			N/R										
Thermal	6	0.90			3.8		15		22.0		5.53		Yes		
	7	0.95			2.8								Yes		
Random	8	0.9			N.G.								-		Strip Fail.
	9	1.10	C	1.10	N.G.	N.G.							-	-	
	10	1.15	D	1.15	3.7	N.G.	18		22.0		5.54		None	-	
	11	1.20	E	1.20	3.2	3.2		19		22.2		5.52	None	None	
	12	1.25		1.25	3.2	3.2							Yes	Yes	
			F	1.30		3.1								Yes	
	13	1.35			3.2								Yes		
			G	1.40		3.1								Yes	
	14	1.50	H	1.50	3.2	3.1							Yes	Yes	
Rerun			I	0.90		3.9	19	21.2			5.06	5.18		Yes	
(No Envir.)			J	0.95		3.6								Yes	
	15	1.00	K	1.00	4.3	3.4							Yes	Yes	
	16	1.05	L	1.05	3.5	3.3							Yes	Yes	
	17	1.10	M	1.10	3.3	2.9							Yes	Yes	
	18	1.15	N	1.15	3.0	2.8							Yes	Yes	
Cold	19	1.35			8.2*				22.1				12.3		*Sus.Run
	20	1.20			4.0								Yes		3Min. Warm Up
Cold Resoak	21	1.45			3.7		18						7.3		
Room Temp	22	1.0			5.0								6.3		
	23	1.05			3.4								Yes		
	24	1.10			3.3								Yes		
	25	1.20			3.2								Yes		
	26	1.30			3.1								Yes		
Hot			O	0.85		3.2	25							6.2	
	27	0.90			3.6				23				5.3		
	28	0.95			3.2								Yes		
	29	1.00			3.1								Yes		
	30	1.05			3.0								Yes		
	31	1.25			2.9								Yes		
Room			P	0.95		3.4		19		22.5				Yes	
	32	1.00	Q	1.00	5.4	3.3	18						6.0	7.0	
			R	1.05		3.2								Yes	
	33	1.10	S	1.10	3.3	3.1							Yes	Yes	
	34	1.20	T	1.20	3.1	3.1							Yes	Yes	
			U	1.30		3.0								Yes	
Add Cold			V	1.15		3.5								Poor	
			W	1.20		3.3								Poor	
			X	1.30		3.1								Poor	
	35	1.35			3.7								Poor		
	36	1.40			3.2								Poor		
Room Temp			Y	0.95		3.2								Yes	
	37	1.0	Z	1.00	3.5	3.1							Yes	Yes	
	38	1.05	AA	1.05	3.5	3.1							Yes	Yes	
	39	1.10	AB	1.10	3.3	3.0							Yes	Yes	
	40	1.20	AC	1.20	3.2	2.9							Yes	Yes	
	41	1.30	AD	1.30	3.1	2.9							Yes	Yes	

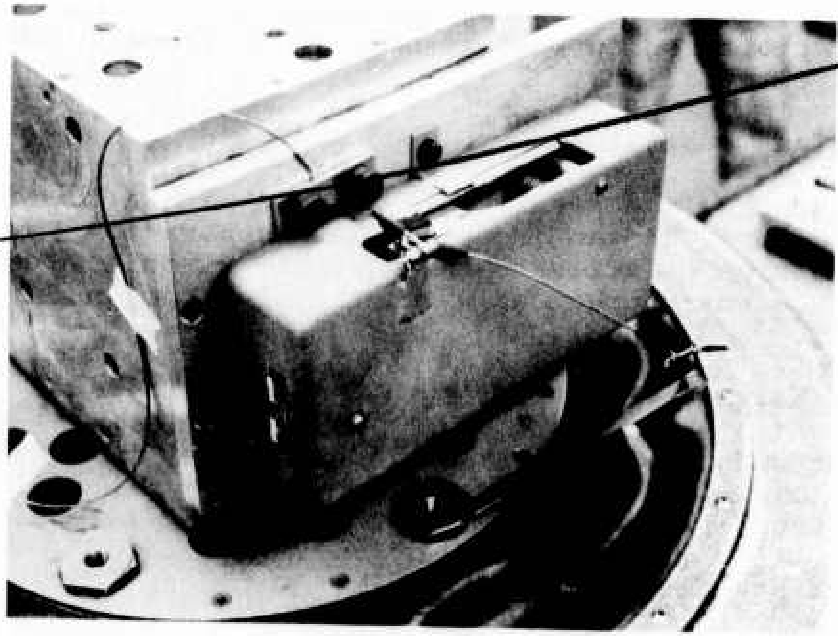


Figure 37. Failed Tear Strip

rectangular tear strip. The location of the ruptured surface was in the area furthest from that where the probe contact occurred. Indications are that the unsupported or undamped portion oscillated or oil-canned during the vibration tests.

4.2.4 Low Temperature

A slight increase in actuation level occurred at low temperature, as might be expected. Times were not significantly affected except in one case (Run 19) where the data are suspect. This resulted in additional low temperature runs being carried out. At low temperature, reset tends to be poor (slow).

4.2.5 Ambient Temperature

In general, actuation levels and times were stable, although some deterioration in performance may be present, as a result of repetitive operations.

4.2.6 High Temperature

Units operated in a predictable pattern with a lower pressure threshold level and an increased safe separation time. Additional voltage to activate the unit was associated with the high temperature environment at which the electromagnetic coil was operating.

4.2.7 Final Ambient Temperature

Both units continued to perform much as they had initially, except for a slight rise in actuation level. S/N 0001 had accumulated a total of 41 operations, and S/N 0002 a total of 30.

4.2.8 Safety Series

S/N 0001 was subjected to a 5-foot drop and a static detonator safety test.

4.2.8.1 Five-foot Drop

The unit was dropped once in the sensitive axis (tending to drive the piston into the armed condition). The unit did not actuate and was operational following the test.

4.2.8.2 Static Detonator Safety Test

The unit was actuated to the intermediate, partially armed condition (probe erected, piston fully strobed, rotor held by the solenoid). The detonator was then fired through leads bypassing the arming switch. Explosive propagation to the lead or MDF line did not occur.

SECTION V

CONCLUSIONS AND RECOMMENDATIONS

In general, it was concluded that the program successfully established the feasibility of using the MAU-116 concept for a universal dispenser safing and arming device. The resulting design met all of the requirements, performed as intended, and appeared to satisfy primary safety requirements. Furthermore, the device shows promise of being producible at a relatively low cost and is sufficiently flexible to allow modifications for a variety of arming levels, arming times, and dispenser installations.

There were test failures that indicated areas which should receive emphasis in any follow-on DSA program. These may be defined under six headings, several of which are interrelated:

(1) Air Piston Size

By definition, the air piston used was taken from the MAU-116 S&A. The piston area was known to be smaller than that desired in the DSA, due primarily to the lower air speeds expected in the latter application. This, in turn, resulted in higher actuation levels than would eventually be required in the various dispenser munitions. Thus future development should start with a larger piston sized to achieve the absolute actuation level required.

In addition, the larger piston would provide a greater amount of arming energy, significantly improving variations in actuation level, arming time and reset, all of which suffered because of the low level of energy and small margins resulting from the small piston size.

(2) Rotor Bearings

Inspection during the vibration test series showed a slow but steady deterioration of the rotor bearing surfaces resulting from sympathetic rotor motion. This in turn contributed to the increase in actuation level, variation in arming times and deterioration of reset. Future DSA units should incorporate an elastic vibration dampening member between the rotor and the probe, similar to that utilized successfully in MAU-116 design.

(3) Piston Shaft Vibration Isolation

Though there was no evidence of any piston shaft bearing deterioration, relative motion between the piston shaft and rotor elements was indicated by some wear occurring at the constant force compression spring ground point interfaces. Incorporation of an elastic vibration dampening member between the piston shaft and the probe, similar to that described in item (2), would minimize the effects.

(4) Rotor Lock

Increases in piston assembly actuation levels were attributed to two factors:

(a) Insufficient piston return spring retention at the battery surface interface,
(b) Inadequate rotor lock bearing design.

Insignificant changes in piston activation levels were experienced when the piston operated independently from the rotor lock after completion of each test. Increasing force levels required to overcome the rotor lock indicated that deterioration of the bearing surface was a major factor in the increased actuation pressure levels required for complete unit operation.

Redesign of the rotor lock mechanism must be accomplished to provide more consistent piston assembly operation.

(5) Timer Reengagement

During the arming cycle, the timer is disengaged from the rotor in order to snap into the arm condition. During reset, reengagement of the timer gear train was noted to be uneven at various times. Greater attention should, therefore, be paid to dimensioning and tolerancing in this area.

(6) Piston Return Spring

Associated with the larger piston, a heavier return spring on the piston would materially improve reset. An improved ground end retention feature as the battery surface interface has been incorporated into the final DSA design but changes in the actual final battery configuration may require further modification.

(7) Probe Vibration Isolation

A single tear strip failure is attributed to vibration induced oil canning of the outer case where the probe does not bear against it. A future DSA design should emphasize optimizing the tear strip design in conjunction with vibration damping of the probe in the unactuated condition. One potential concept is the conversion of the transfer bar discussed in paragraph 2.2.6 to an elastic or spring member that interacts with the "rip off" seal section.

(8) General Product Engineering

While it is not proposed that any changes in concept be incorporated in the next stage development, the entire design should be reviewed from a design-to-cost viewpoint. There are a number of areas in which significant cost savings could be achieved. As a single example, the solenoid arrangement included in the prototype DSA unit is a relatively expensive element for which a lower cost substitute could be designed.

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